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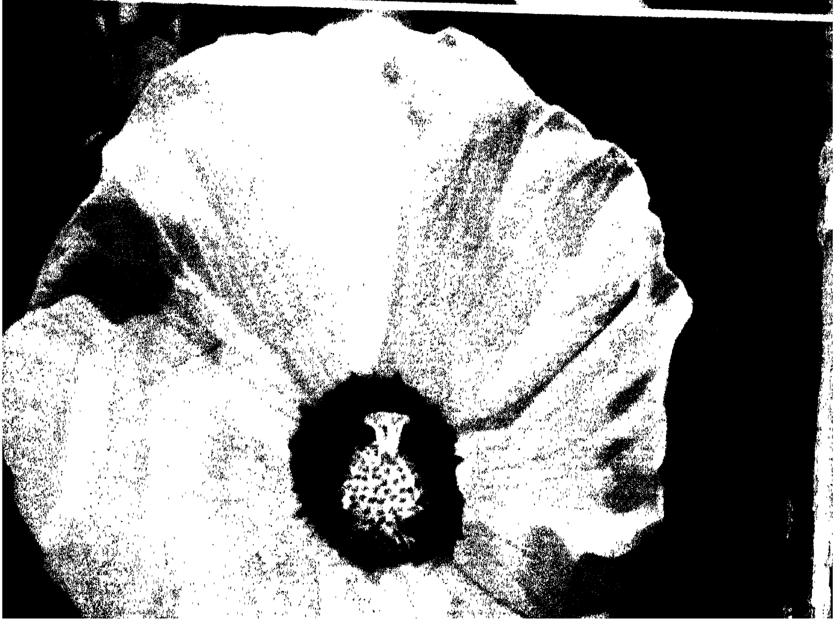

NEW
INTRODUCTION TO BIOLOGY

By

ALFRED C. KINSEY D.Sc. (HARVARD)

502 ILLUSTRATIONS

522 PROBLEMS

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. . . That it is an interesting world
in which we live . . .

PREFACE TO THE REVISED EDITION

For those who have not known the earlier editions of *New Introduction to Biology,* it should be said that the text is the outgrowth of a boyhood interest in the out-of-doors, and of thirteen years of work in the summer camps. The book is consequently dedicated to the task of interesting boys and girls in the living world.

As a research scientist, concerned with the technical details of a single small bit of the living world, I am still impressed with the importance of giving these boys and girls a bird's-eye view of the world as a whole, an idea of the unity of life processes in plants and in animals, and some grasp of general principles for which they may find illustrations in such everyday organisms as they already know or are likely to meet. The course is consequently (1) a survey course, (2) a unified course, (3) a principles course. The pedagogical defense for such a program is the fact that it does interest high school students. This seems abundantly attested by its success with some hundreds of thousands of such students during the past twelve years.

The bases of the course are scientific principles, with practical applications used as illustrations of the generalizations. Important as economic, dollars-and-cents aspects of biology may be, it seems more important that the boy and girl learn that life is worth the living. While the text includes extensive treatments of such practical things as control, conservation, hygiene, nutrition, and disease, even more attention is paid to merely interesting things. Biology can contribute very much to the happiness of the world, and that is the most practical thing about it.

The pedagogical problems of the introductory course are examined in detail in the author's volume, *Methods in Biology.*[1] The volume includes an extensive treatment of the content of the course, the organization of units, the laboratory and field program, suggestions for independent projects, an examination of the available devices for testing and measuring student accomplishment, and notes on specific teaching problems in each of the seven sub-sciences which are the units of the present text. There are lists of teaching devices, sources for supplies, reference books, etc. The material is so completely covered in *Methods in Biology* that there is little need for including pedagogical advice in this text.

It should, however, be noted that the attempt to serve all parts of this highly diversified land has resulted in a volume larger than any single class may be able to cover. This should allow each teacher to emphasize what is of especial interest and concern in the particular community, and to omit other topics which have been included. Many of the chapters are so written that they may be passed by without breaking the continuity of the program.

A field and laboratory program designed to accompany the present text is available in *Workbook in Biology,* also published by J. B. Lippincott Company.

The present edition of *New Introduction to Biology* differs from its predecessors in some modifications which, experience has shown, may add to its teaching value. Corrections and additions will bring it up to date with our growing science. The first two chapters have been rewritten to provide a simpler approach to the course. The teaching materials at the ends of the several chapters have been augmented by nearly three hundred new problem questions. The new illustrations which have been added should provide further means for capturing the student's interest and adding to his store of knowledge. A new chapter on Conservation summarizes the conservation material which is scattered through the unit on Ecology. There is augmented material on the History of Science, and extensive additions to the teaching material on Scientific Method.

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[1] Kinsey, A. C., *Methods in Biology* J. B. Lippincott Company, Chicago, 1937. $2.50.

ALFRED C. KINSEY

Bloomington, Indiana

ACKNOWLEDGMENTS

Much of the material in this book has been taken directly from original sources rather than from other textbooks. It would be unwarranted to acknowledge all of these authorities in the body of an elementary text, although that is our chief debt in any science book.

With twenty-five years and seventy-five thousand miles of fieldwork to draw upon, the author has utilized his personal experience in giving specific illustrations of many principles. The chapters on *Taxonomists as Explorers,* much of the material in the unit on *Distributional Biology,* and the chapters on *Individual Variation* and on *New Kinds of Organisms* represent the author's own field of research. A large part of the material in this book has not yet appeared in any other high school text.

A number of research scientists, in many instances the leading experts in their special fields, have helped eliminate errors of fact from the various editions of this book. For the errors that have survived, and for the opinions expressed in the text, the author must assume full responsibility; but he wishes to acknowledge aid as follows:

Dr. R. M. Anderson, of the Canadian Arctic Expedition: in the references to the Arctics, Chapters X and XXI.

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Dean William F. Russell, Teachers College, Columbia University, who sympathetically edited the original edition of this volume.

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Robert Bates, of Bloomington, Indiana, who similarly gave me the benefit of the beginning student's viewpoint.

My wife, Clara McMillen Kinsey, who has generously contributed in the making of the whole volume.

The halftone figures and drawings in this book represent the work of more than two hundred eighty artists and photographers. It would be as impossible for an author personally to originate such a treasure of illustration as it would be for one man to provide, through his own research, all the data for a textbook in biology. The generosity of those who have contributed the material is poorly acknowledged in the credit extended with each figure.

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NEW INTRODUCTION TO BIOLOGY

(REVISED)

CHAPTER I

BIOLOGY

Biology is the science of life.

We shall study all kinds of living things, both plants and animals, in this course in biology. There are trees or grasses, flowers or weeds, birds or insects—living things of some sort along every path in this world. Yes, we ourselves are part of this living world, and that is one reason for studying biology.

Courtesy Dr. A. R. Cahn and Nature Magazine

FIG. I.—LIFE

A Chippewa Indian boy, northern Minnesota.

While we may handle plant and animal material that is no longer alive after it reaches us, in the classroom and in the laboratory; and while we shall talk and read about some things without actually handling them, do not forget that every story in the biology book began with a living organism.

This Interesting World

But what is life? Can you tell what it is made of, where it came from, how to measure it? Can you tell precisely what are the differences between a dead leaf and a live one? What can a live thing do which a dead one cannot? You have known living plants and animals ever since you could think, but have you ever stopped to wonder what it was in them that made them alive? Life, like many other things, is so common that we do not often enough stop to marvel at it.

Let me show you what a remarkable thing we are studying. Let me tell you of eight snakes with which I experimented one year.

As the autumn advanced, they ran out of food; so I put them into a box of earth and buried them two feet or more in the garden soil. That was in the state of Maine, where things freeze early in November and stay frozen until late in April or May. Snow piled deep. For a week our thermometer recorded twenty-five below zero. For months the ground lay frozen, possibly beyond the depth of the snakes. They were without food and without water, where little air could reach them, where the temperature stayed near freezing, and where they themselves may have been frozen for part of the time. At the end of six long months, in the month of May, I dug up the box—and eight snakes crawled out of it, alive!

Can you tell what sort of thing it was that could stand such treatment? You say it was life? Have you explained it?

It is very difficult to answer such questions. Our knowledge of life is still very inadequate. There are many things that we shall learn about organisms, but many that no man can tell us.

There are surprising things everywhere about us. As one more example, listen to the story of the redwoods and the big trees, two similar evergreens found in the mountains on our Pacific Coast. The bark on these trees is spongy and very thick, protecting the growing parts of the trunks from insect attacks and sometimes from forest fires. This has allowed the trees to keep growing for hundreds and thousands of years. Old specimens are of great size, but their size is of less interest than the great ages they have reached. By counting the rings in the cut stumps, it is known that some of these trees lived for over 2,000 years, and one still standing is estimated to be 4,000 years old. Such an age is almost as great as that of all recorded human history, dating back through Revolutionary days, past the time of Columbus's discovery of America, the time of Charlemagne, the birth of Christ, and still back through most of the

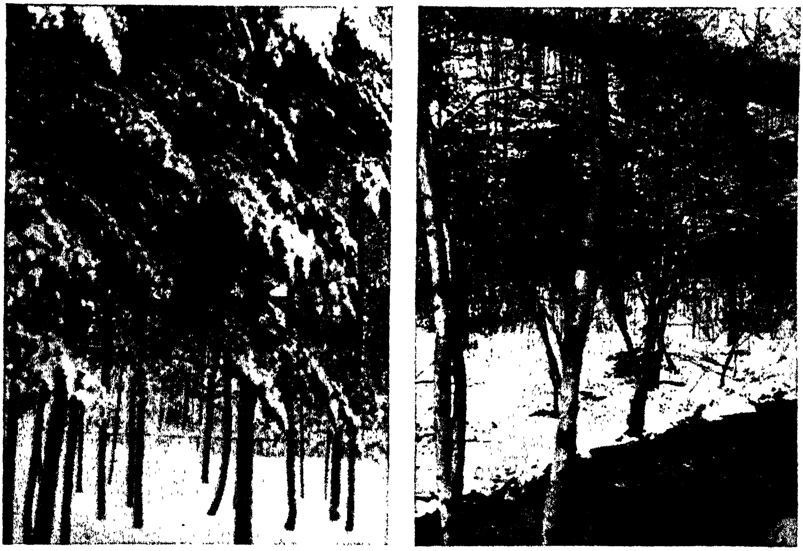

FIG. 2.—ALIVE, ALTHOUGH FROZEN
White pine in Maine, and woodland along a stream in northern New Jersey.

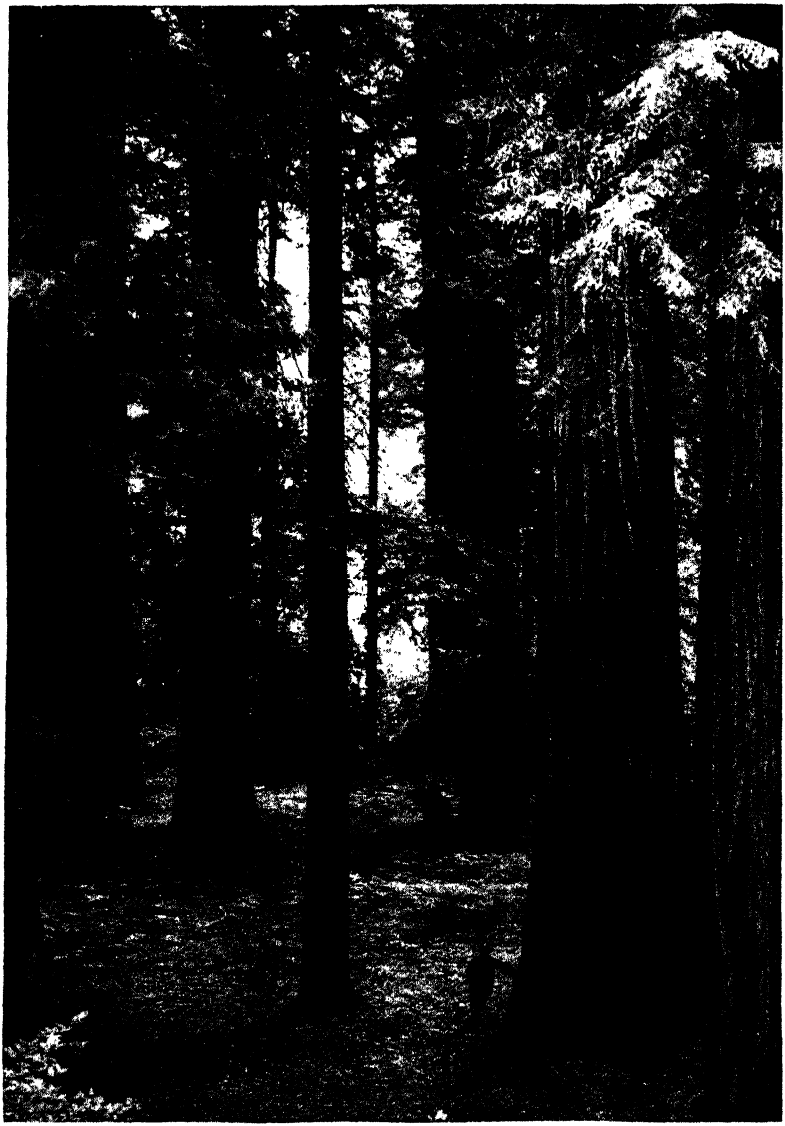

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FIG. 3.—CALIFORNIA REDWOODS

events described in the Bible, even to the days of Abraham. In that remote year the seedling of this plant began to grow, in the same spot where the tree still stands and grows in the heart of the Sierras of California.

What an interesting world this is in which we are living! If this biology course convinces us of that, we will feel repaid for spending our time in it.

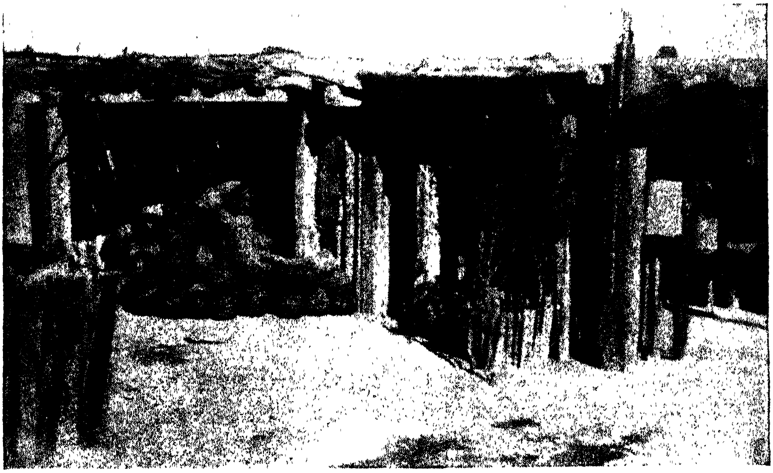


FIG. 4.—PRACTICAL IMPORTANCE OF BIOLOGY
Man's food, shelter, and flowers for his enjoyment—all a part of the living world. Native hut in northern Mexico.

Practical Values in Biology

Some of the things we shall learn may be of very practical value—of dollars-and-cents importance—to us. If we learn how our own bodies are made and how they work, we should be able to use them more fully and more happily.

If we learn which organisms (plants or animals) are our friends and which are enemies, we may learn to live more wisely with these other creatures with whom we share the world. Some of them, both plants and animals, provide our food; others are the sources of our clothing and of some of the materials which are built into our houses. Some of them, like some of the insects and the fungi, would like to eat our own foods and fiber plants; and we must continually wage war against them in order to grow our crops and preserve them for our own use. Birds help us by eating insects. Forests are of importance to us, not only as sources of lumber, but as means of protecting our lands against damage by rain, winds, floods, and droughts. Some of the organisms which are microscopic in size are the germs that inflict certain diseases upon us. Others of the microscopic forms are the magicians that turn parts of the air into the foods in the plants which we eat. A more complete list of our relations with other organisms should impress everyone with the importance of biology in the lives of every man and woman.

Scientific Method

And finally, in the course of the year we should begin to learn how to be scientific. For biology is a science. In a science we learn by using our eyes, our ears, and the other sense organs by means of which we observe things. Scientists do not consider mere opinions worth very much. They think observation is better than reasoning—better than figuring out how things should be. We do not take anyone else's word if it is contrary to what our own senses show us are the facts in the case.

The present century has been called the Age of Science. Science is responsible for many of the best things which we use and enjoy in our everyday lives. There are a number of sciences: biology, physics, chemistry, geology, astronomy, and others. But all kinds of scientists agree in believing that observation provides the best means for determining most of the facts of the universe. In this biology course we may learn how to be scientific in our thinking about plants and animals.

SUMMARY

Review what you have just read. Be prepared to **explain** and to **give illustrations** of each of the statements in the following summary of the chapter.

1. Biology is the science in which all kinds of living things are studied.
2. Common as it is, life is a most remarkable thing—so remarkable that even the most learned scientists do not understand all about it.
3. The stories of the frozen snakes, and of the California big trees, are samples of the many interesting things to be found in the out-of-doors. In learning how interesting a world it is in which we live, we have the first reason for studying biology.
4. Some knowledge of biology may prove of practical value to every boy and girl, man and woman. This is the second reason for studying biology.
5. In this course, we may learn how to be scientific—and this is the third reason for spending a year in the study of plants and animals.

PROBLEMS

The problem questions that are to be found at the end of each chapter in this book are not answered in the text; but you should be able to think out original answers if you understand what is in each chapter, and connect it with your own experiences with common plants and animals.

1. Why have you chosen to study biology this year? What good do you expect to get out of the course?
2. What is the most interesting thing that you, yourself, have ever observed about a living plant or animal?
3. Why is it worth while learning that this is an interesting world in which we live? Spend some time thinking about your answer before you give it.
4. What can living creatures do that dead things cannot do?
5. Make a list of some of the things you think all of us should know about our own bodies, in order that we may use them to better advantage.
6. Make a list of some plants which you think have been useful to you; and be ready to explain how you used them.
7. Make a list of some useful animals, and explain how you have used them.
8. Make a list of animals which you consider enemies to man; and be prepared to explain how they damage us.

9. Make a list of plants which you consider enemies to man; and explain how they damage us.

10. List some of the ways in which science makes life better for us than it was for people of, say, George Washington's time.

11. List some commonly-held ideas about plants or animals, which you think are incorrect because they are not scientifically proven.

12. Do you think everyone should be scientific about everything? There is something to be said for and against this idea. Be prepared to discuss it in class.

13. What other reasons can you give for the study of biology, in addition to those given in this chapter?

all the plants; in the other are the animals. Usually there is no difficulty in distinguishing a plant from an animal.

Plants are in most cases distinguished by the fact that they have a certain green material, called **chlorophyll,** in them. This is the thing that makes most plant structures look green. Our common animals do not have chlorophyll in them. Because plants have this green chlorophyll they are able to manufacture their own sugar or starch foods (in ways which we shall study later); since animals lack chlorophyll they cannot manufacture their own foods, but have to depend directly or indirectly upon plants for their foods.

In addition to the chlorophyll, most plants have a peculiar wood-forming material, called **cellulose,** in them. The woody trunk of a tree, that part of it which we may burn as firewood or use as lumber for building furniture or whole houses, is for the most part made up of cellulose. The stems of smaller plants, and even the leaves of such lowly things as the grasses, keep as stiff as they do chiefly because of the cellulose in them. Animals almost never have cellulose in their structures, so any organism which we find containing cellulose, or wood, may be labelled a "plant" in our scheme of classification.

Another way to distinguish plants from animals depends on the fact that plants ordinarily move very slowly—indeed, so slowly do they move that most people do not think of plants as moving at all, unless they are shaken by the winds or moved by other outside forces. Most animals, on the contrary, are able to move quite rapidly.

In the same way, plants are ordinarily less sensitive than animals. They cannot feel, see, hear, smell, or be affected in the other ways in which most animals are easily affected. No part of a plant blinks when a light is shone squarely upon it. Upon touching a hot stove, a plant would not jump off as quickly as most animals would move from the same place. The sensitive things that we find may be classified as animals, the less sensitive things as plants.

There are exceptions to these rules for distinguishing plants from animals, just as there are exceptions to most other rules; but we shall not ordinarily encounter difficulties in classifying the organisms that we find as either plants or animals.

Plant Groups

Following the accepted system, we may further classify the plants that we find into four great groups. One of these groups includes the most simply constructed plants, the *thallus plants*. Another includes the *mosses and liverworts*. Another includes the *ferns* and what are called the *fern allies*. A fourth group includes the *seed plants*.

The first things that we are likely to find, since they are the largest and most conspicuous in most regions, are seed plants. All of our trees are seed plants. All other flowering plants, the weeds, and the grasses are also seed plants. The green clothing which covers so much of the earth is made up largely of seed plants. Biologic classifications begin with the organisms that are the simplest in structure; so the simpler thallus plants are placed first and the seed plants are fourth in the scientific classification noted above. But in beginning our exploration of the living world, it will be easier to study the larger and more conspicuous plants first; and so we shall reverse the scientific order, and first learn something about seed plants.

Seed Plants

When people talk about *plants,* they are thinking usually of these seed plants. Ferns, mosses, toadstools, and seaweeds are not seed plants; but the trees, all the wild and cultivated flowers and weeds, the grasses of our lawns and fields, nearly all of the plants that we eat, nearly all of the plants that we use for making clothing, furniture, and houses—indeed, most of the plants that we meet are seed plants.

How can one tell a seed plant from a fern, one of the mosses, or a plant of any other group?

In the first place, seed plants have leaves, stems, and roots. This is true of the common plants that you know. Moreover, seed plants have veins in their leaves. You will recall the veins that are so readily seen in most plant leaves. Veins are continued down through the stems and the roots, so that water (sap) circulates through them into every part of the plant.

Finally, seed plants develop flowers from which seeds ultimately form; and these seeds, when properly planted, give rise to new plants of the same kind.

FIG. 6.—THE CONSPICUOUS PLANTS ARE SEED PLANTS

Grasses, evergreen and broad-leaved trees, wild flowers, and shrubs. In northern New Jersey.

No other group of plants has just this combination of characters: leaves, stems, roots, leaf veins, flowers, and seeds.[1]

Seeds.—The seed plants are so named because, of all their structures, the most important are the seeds from which the new plants develop. This method of forming new individuals, this type of *reproduction,* as we say, is quite different from the method of reproduction in the other groups of plants.

---

[1] The ferns have all of these characters except the flowers and the seeds. The mosses have leaves and stems, but none of the other structures. The seaweeds and toadstools have none of these structures which are in seed plants.

Seeds form as the result of the growth of eggs which are located inside the flowers of seed plants. Sometime later we shall learn more about this method of reproduction. It is enough now to point out that seeds are always formed inside of flowers.

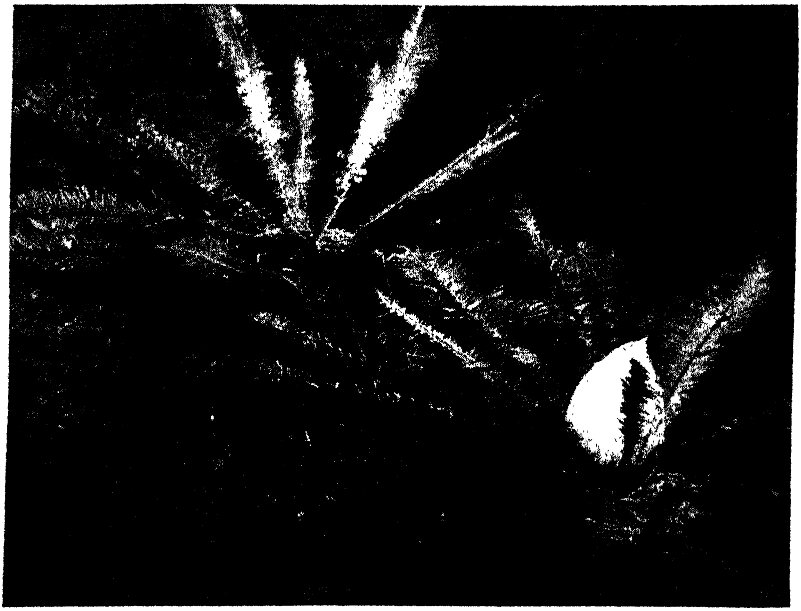


FIG. 7.—CYCADS

Living relatives of the most ancient of all seed plants. Northern Mexico.

All seed plants, therefore, normally form flowers. While the conspicuously colored flowers of many plants are well known, it is not commonly realized that the less conspicuous structures of many trees, grasses, and common weeds are just as truly flowers, inasmuch as they contain eggs which may grow into seeds.

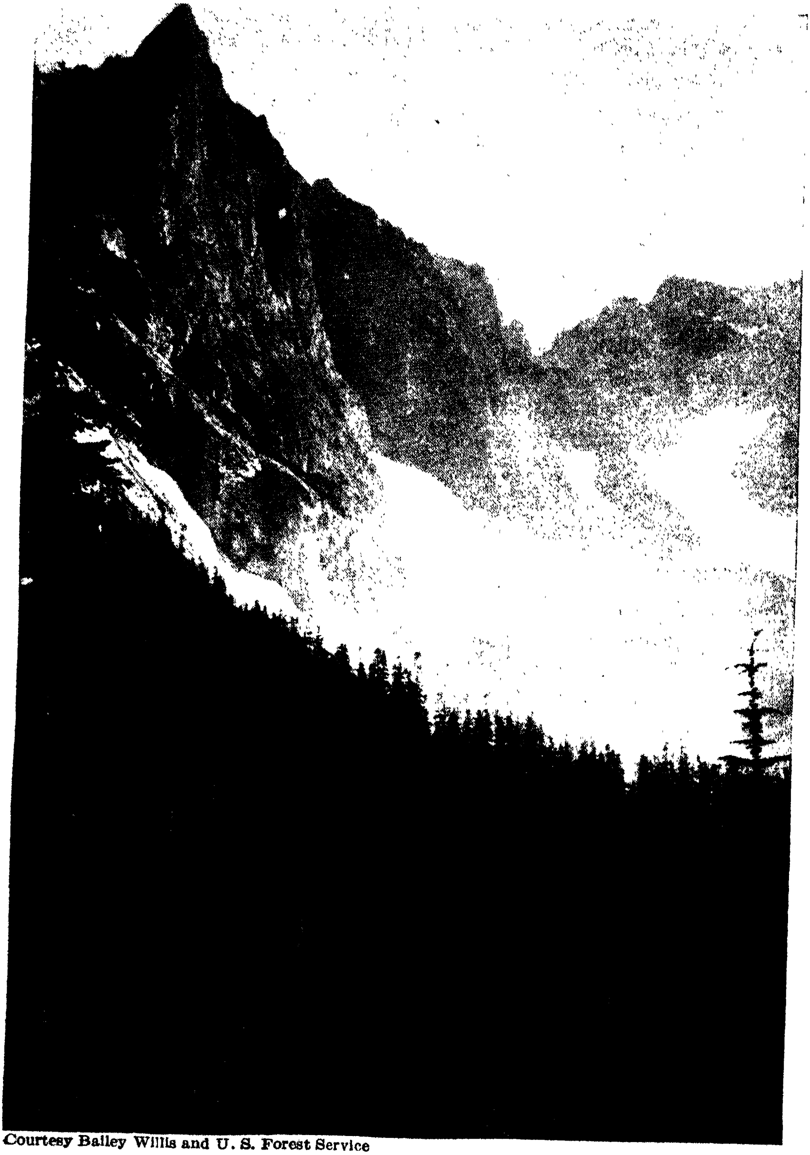
The many kinds of seed plants may be classified in three groups.

GROUP I. **Ancient Seed Plants.**—The first seed plants which ever existed in the world, living tens of millions of years ago (as the geologists tell us), were seed plants related to the cycads which now grow in the tropics in several parts of the world. Most of these ancient seed plants are now extinct—dead and gone. The illustration on page 16 shows one of the few surviving species, a Mexican cycad which looks somewhat like a palm.

The Asiatic ginkgo, often planted as an ornamental tree in America, is another kind of ancient seed plant. Which of you has ever seen a ginkgo tree growing?

The commonest of these ancient seed plants are the well-known "evergreen" trees or **conifers**, as we prefer to call them. They are called conifers because most of them bear cones. Their seeds are produced inside, in papery coverings at the bases of the scales which make up the cones. The many kinds of pines, spruces, hemlocks, firs, redwood, cypress, larch, and cedar, common in many parts of North America, are conifers. They are beautiful trees with small, usually evergreen, needle-like, or scale-like leaves. They are the chief beauty of the North woods of the United States and Canada. There are also extensive pine areas in our South, and cedar areas in the northern Rocky Mountains. Throughout our western mountains, and over the high mountains of Mexico and Central America there are beautiful stands of evergreen forests. The conifers are the most important of all our sources of lumber; they provide the pulp from which most of our paper is made; and they furnish tars, gums, turpentine, and other products of commercial importance. As shrubs and trees for ornamental plantings about our homes, the conifers are held in high favor in many parts of our country.

GROUP II. **Monocotyledons.**—The seed plants of the second and third groups are called *monocotyledons* and *dicotyledons*. These are ungainly names, but we have none better. These names have been given because the seeds of all these



Courtesy Bailey Willis and U. S. Forest Service

FIG. 8.—CONIFERS IN THE MOUNTAINS OF WASHINGTON STATE

plants contain cotyledons: one cotyledon in the seed of a monocotyledonous plants, two in each seed of a dicotyledon. The two conspicuous halves of a bean are its two cotyledons; the rest of the young bean plant lies between these and is small and inconspicuous. The cotyledons are peculiar leaves which store up the food upon which a young plant feeds during its first stages of growth. In the corn seed, on the contrary, there is only one cotyledon, the entire seed being filled with that cotyledon and with the other parts of the young plant.

Without examining the seeds of a plant, it can be classified as a monocotyledon or a dicotyledon by the arrangement of the veins in its leaves. The leaves of a dicotyledonous plant usually have a net-like arrangement of veins. The leaves of monocotyledons, on the other hand, usually have parallel veins. These differences between monocotyledons and dicotyledons are shown in the accompanying illustrations.

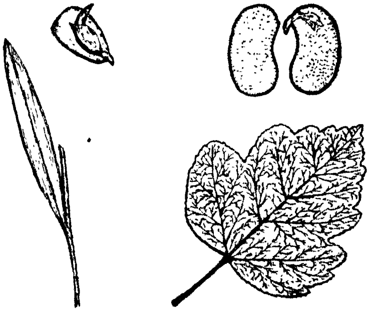


FIG. 9—COTYLEDONS AND LEAF VEINS

In a monocotyledon (left), and in a dicotyledon (right).

Monocotyledons are abundant and economically very important. Only a few of them, chiefly plants of the tropics, are trees. In our own country only the yuccas and a few palms grow tall; the rest of our monocotyledons are smaller plants like the cat-tails, sedges, jack-in-the-pulpits, skunk cabbages, calla lillies, trilliums, and orchids. Most of our early spring flowers coming from bulbs belong to this group, furnishing the cultivated crocuses, daffodils, hyacinths, tulips, and lilies which are grown in our spring flower gardens. Such commonly eaten bulbous plants as the onions, other foods and flowers like asparagus, irises, and day lilies are also monocotyledons. And, finally, the grasses are monocotyledons. Grasses cover much of the earth; their roots

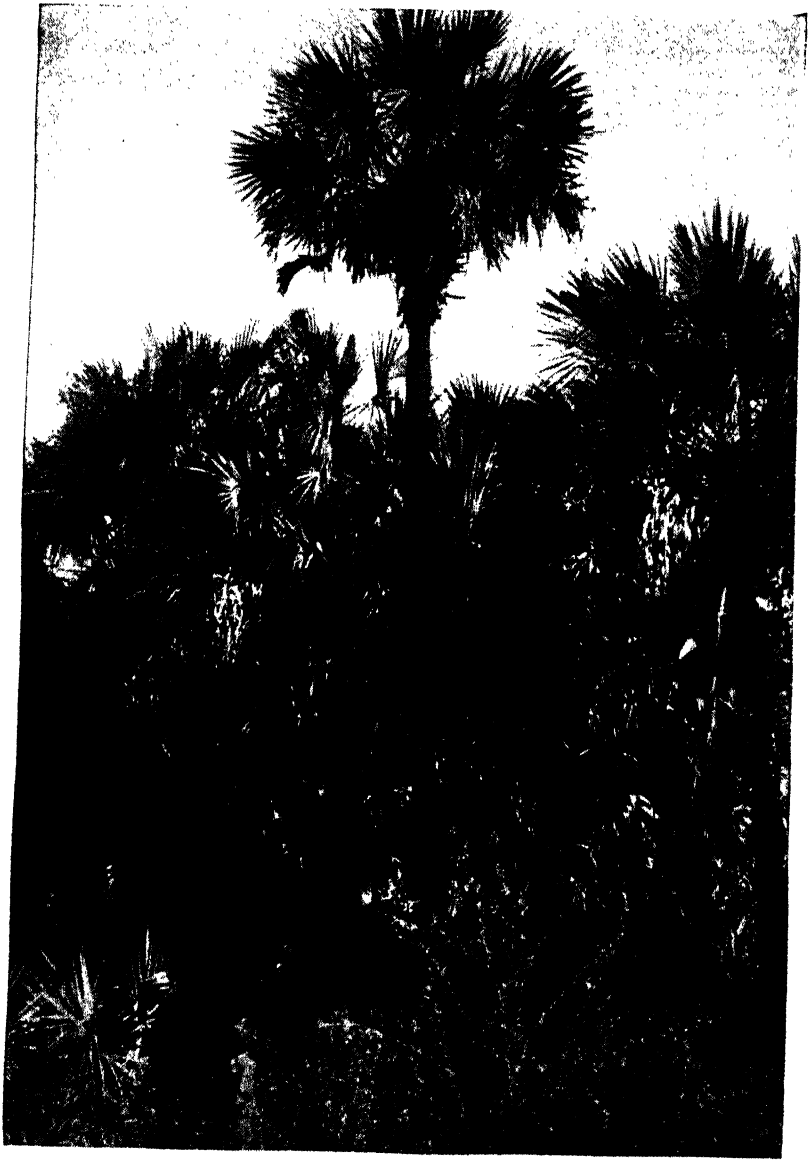
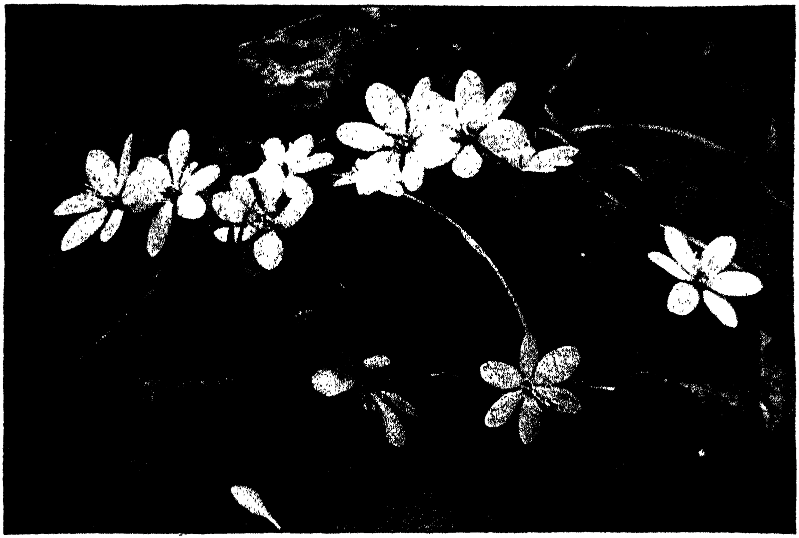


FIG. 10.—MONOCOTYLEDONS AS TREES

Palms in the tropics of eastern Mexico. Note the man in the lower left corner.

hold together the soil of hillsides and embankments; and hay, oats, wheat, barley, rye, millet, corn, and sugar-cane are grasses of very great importance to man. In fact, the monocotyledons, although not as abundant as dicotyledons, furnish notably large portions of our human food.

Dicotyledons.—This group of seed plants includes all of our common trees except the conifers. That means that the willows, poplars, hickories, walnuts, butternuts, beeches, chestnuts, oaks, elms, magnolias, acacias, laurels, sycamores, locust trees, sumacs, maples, box-elders, dogwoods, lindens, tulip trees, ashes, and many others are dicotyledons. These are mostly broad-leaved trees which lose their leaves each winter. These are the trees of our forests everywhere except in the evergreen areas of the North and in parts of the South. All of our fruit trees, including apples, pears, peaches, apricots, plums, cher-



Courtesy L. W. Brownell

FIG. 11—IN THE SPRING WOODLAND

Hepaticas are among the first to bloom. These are dicotyledonous flowers.

ries, oranges, lemons, and others are also dicotyledons. Practically all of the shrubby plants which cover so much of the deserts and mountainsides, and which are planted as ornamentals around our houses, are also dicotyledons. Such well-known flowers as buttercups, poppies, cacti, roses, sweet peas, clovers, wild carrots, milkweeds, violets, daisies, sunflowers, golden rods, asters, and dandelions have net-veined leaves and two cotyledons in each seed. Most of our so-called vegetable crops—peas, beans, carrots, tomatoes, potatoes, cabbage, turnips, melons, cucumbers, celery, and beets—belong here. Most of our commonest plants are dicotyledons.

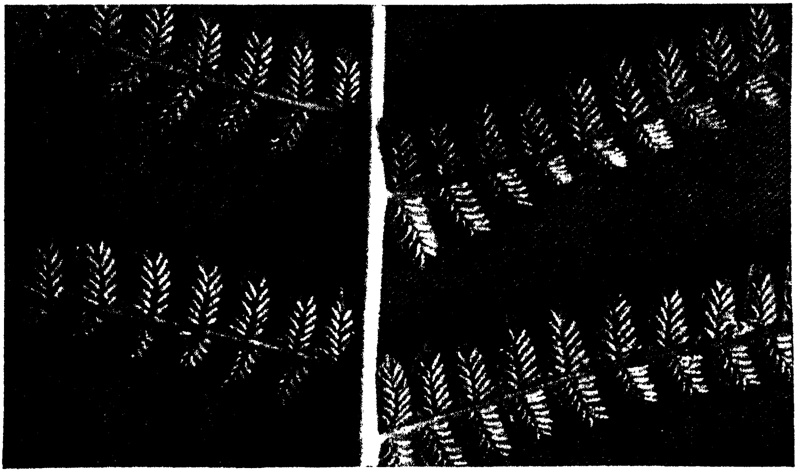
Although they are so prominent, the seed plants in any region may number only two or three thousand species. It is not an impossible task to learn the names of the more conspicuous ones. To be on speaking terms with these plants, with the weeds as well as with the brilliant flowers, and to know where they grow, how they grow, what insects visit them, and other such things about them does much to make the world interesting. You should get some book that will help you, and learn the names of the common trees and of the more conspicuous flowers of your region. For a list of usable books, see the bibliography at the end of this unit on Taxonomy. You will find it one of the most delightful of all pastimes, if you will get out-of-doors and become acquainted with the plants in the world about you.

Ferns and Fern Allies

The plants that belong to this group have distinct stems, leaves, and roots. In these respects they resemble the seed plants. They also have veins, which are the structures through which the sap of the plants flows, and in this they are, again, like the seed plants.

The ferns differ, however, in their method of reproduction. They do not have flowers which give rise to seeds. Instead, reproduction is accomplished by small and very simple structures called spores. To the naked eye, these spores look like brownish, dust-like grains that are borne in clusters on the under surfaces of the fern leaves, or sometimes on separate stems. Perhaps you have mistaken these spore clusters for diseased spots on the leaves.

The spores of ferns differ from the eggs of flowering plants in not being developed inside of flowers, in not giving rise to seeds, and in their simpler and more direct method of growth.



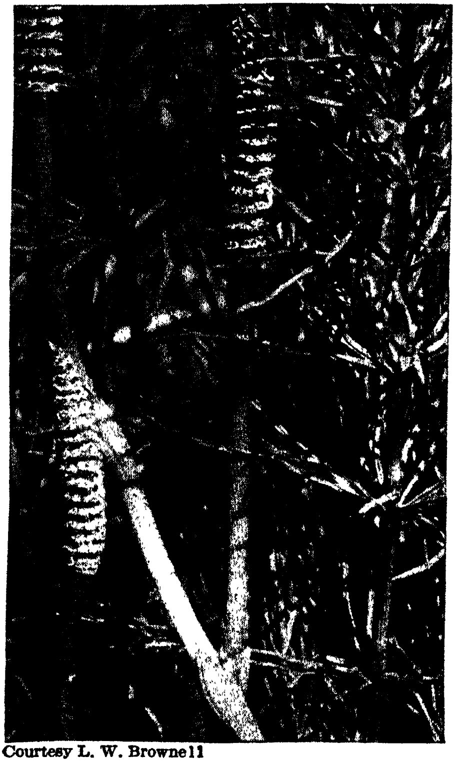
Courtesy L. W. Brownell

FIG. 12.—SPORE SACS ON THE UNDER SURFACE OF A FERN

When a spore falls into the ground, it grows directly into another plant.

The astounding thing about the reproduction of a fern, however, is the fact that the new plant which comes from the spore is not like the leafy fern plant at all. It is a flattened, irregularly rounded body about the size of a small fingernail. These plants, called *prothallia* (*prothallium* in the singular) are too small to be easily observed in the woods, but they may be found in moist greenhouses. The prothallia reproduce *sexually,* as we say, producing eggs which are more like those of seed plants; and although they do not form seeds, their method of growth is more like that of the seed plants.

When the prothallium reproduces, it gives rise to the leafy, familiar fern plant again. There is thus an *alternation of generations* among the ferns. The leafy, spore-bearing plant gives rise to a sexual generation, the prothallium; the prothallium gives rise to the sporebearing generation; and so sexual and sporebearing generations alternate. Each plant resembles, not its parents but its grandparents! It is a remarkable method of reproduction found not only among the ferns and fern allies, but among the mosses and even among some of the animals.



Courtesy L. W. Brownell

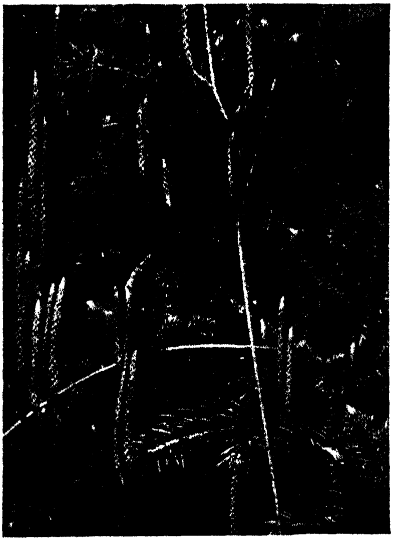
FIG. 13.—COMMON HORSETAIL

Spore-bearing plants in front, green and leafy plants behind.

Ferns also multiply from underground stems which may be very long-lived, for they grow on from year to year, the old ends dying as the new parts develop.

Ferns are found mainly in moist places. There are relatively few species in the United States, although they may form dense stands in the damper woodlands. Ferns are much more abundant in the tropics, where some of them grow as trees forty feet in height with trunks of considerable diameter.

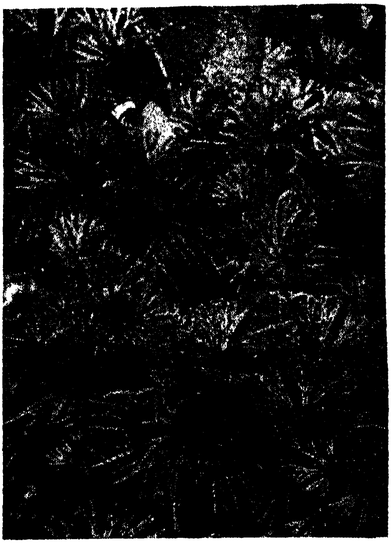
Fern Allies.—The best known of the fern allies are the horsetails and the club mosses, plants which look very different from ferns, although they are similar in structure and methods of reproduction. Bare, leafless, spore-bearing stems of horsetails occur commonly in the late spring in old fields and along railroad embankments. Bushy, leafy stems which are food factories grow at later seasons from the same plants. Some species of horsetails grow in swamps and in deep woods. They often contain enough silica, a sand-like material, to make them feel rough, for which reason these plants were used on pots and pans as the "scouring rushes" of the early settlers. If a horsetail is placed in a weak acid, its plant tissue is eaten away, leaving a delicate, glass-like skeleton.



Courtesy L. W. Brownell

FIG. 14.—A BUSHY TYPE OF CLUB MOSS

One of the fern allies. Showing foliage leaves and spore-bearing cones.



Courtesy L. W. Brownell

FIG. 15.—ANOTHER TYPE OF CLUB MOSS

The trailing Christmas green, common in more northern woodlands.

Club mosses are low, leaf-covered, and furry, bushy, or finger-like plants that grow commonly on the ground in moist woods, especially farther north. They are not really mosses, but fern allies. Some species have vine-like stems, and these are used for making Christmas chains. The yellow spores of many of the species are very abundant, and are known as *Lycopodium*, which is sometimes used by druggists when they need a very dry powder. This powder burns with such a bright flash that it may be used in making some kinds of fireworks, and it is usually possible to set off the spores in the open woods.

On the whole, the ferns and fern allies are represented by a very few species in the world today, but ages ago they were the most prominent plants in existence. In the Coal Age, something like three hundred million years ago, ferns, horsetails, and club mosses formed forests of tall trees (see Fig. 278). It was then that the fallen plants accumulated and were transformed into the coal which we now mine and burn. The horsetails of today number but forty species in the whole world—the last remnants of a group that is fast becoming extinct.

In any one region of the United States or Canada, the kinds of living ferns and fern allies are so few that it is quite possible to become familiar with all of them by name. They cover so much of the moist woods' floor that it richly repays one to become well acquainted with these plants.

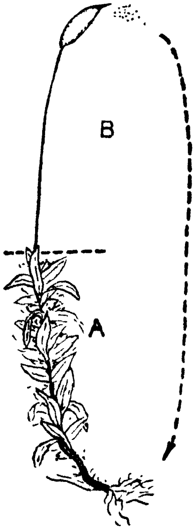


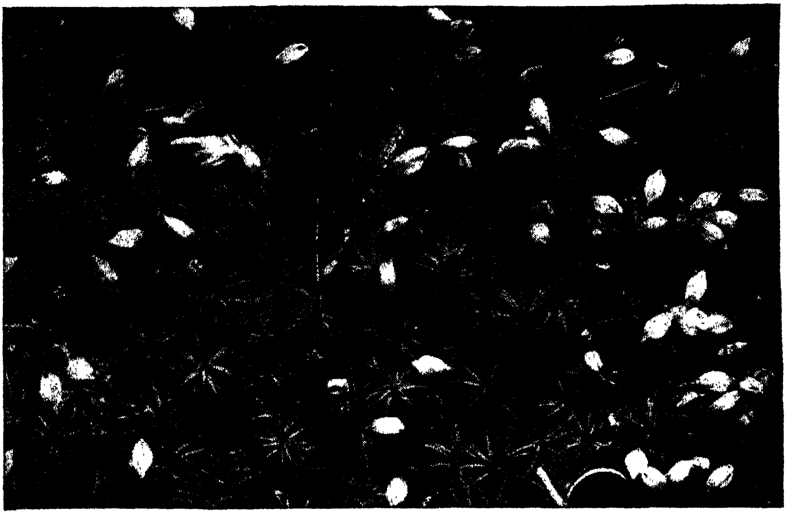
FIG. 16.—ALTERNATION OF GENERATIONS IN A MOSS

A, the leafy, sexual generation. B, the leafless, spore-bearing generation.

Mosses and Liverworts

Mosses.—The mosses have distinct stems and leaves, but they do not have roots, they do not have veins, and they do not have flowers. Like the ferns, the mosses reproduce with an alternation of generations. Unlike the ferns and the fern allies, the mosses have a sexual generation which is prominent. This sexual generation is the leafy, familiar moss plant which you know. It reproduces by means of eggs which are located often in the topmost cluster of leaves on this moss plant. When these eggs grow they give rise to plants that are strikingly different from the leafy parent.

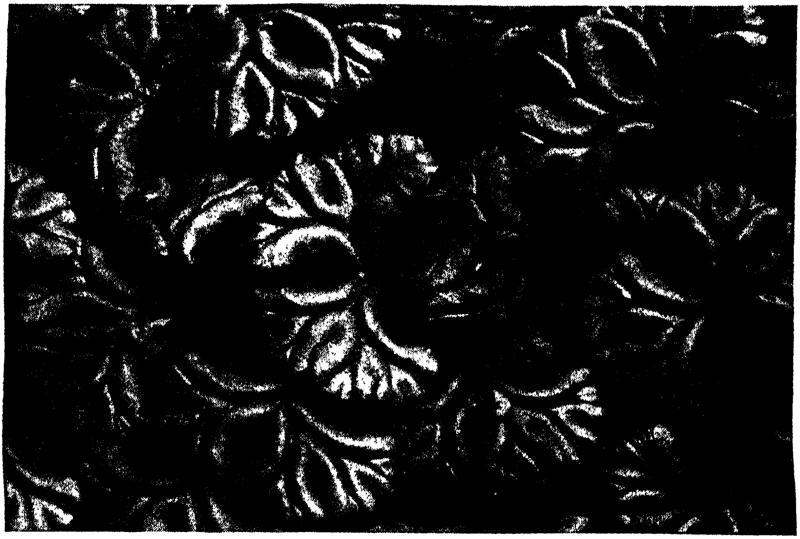
This second generation of a moss plant is a leafless, stem-like structure that forms on the top of the leafy plant and remains attached to it. At the tops of these stems one may find small capsules which contain powdery spores resembling those of the ferns. The capsules are popularly but incorrectly referred to as the "fruits" of the moss plant, but they are not true fruits because they do not contain seeds, but contain spores instead. When a spore falls into the ground, it grows into another leafy, sexual moss plant.



Courtesy L. W. Brownell

FIG. 17.—MOSS PLANTS, SHOWING BOTH OF THE ALTERNATE GENERATIONS

Mosses are common on the ground, on stones, and on trees in regions of considerable moisture. Mosses often cluster upon the moist side of a tree or rock; but since that is merely the most shaded or most sheltered side, and not necessarily the northern side, a woodsman cannot safely use them for guides. Although few species of moss live in standing water, there are some water-inhabiting kinds which may completely fill our northern bogs. These bog species are important because after they die they become compressed, often in quantities, and turn into peat, a material which may be burned as fuel. This same peat, in a dried or powdered form, is extensively used for mixing with garden soil so that the peat, with its great powers for absorbing water, may keep the ground moist about the roots of the cultivated plants. Some peat mosses may absorb as much as fifteen or twenty times their own weight of water, and this is why the moss is a favorite material for packing about the roots of nursery plants which are being shipped to new locations. During war emergencies peat moss has even been used in the dressing of wounds. The moss has greater absorptive value than the better-known absorbent cotton used in times of peace, and



Courtesy L. W. Brownell

FIG. 18.—A COMMON FORM OF LIVERWORT

it is interesting to find that the moss contains a substance which kills germs, thus acting like an antiseptic as effective as some of those sold by the druggist.

Liverworts.—These plants often grow in moist places and in water. They are more common in the Southeastern portion of the United States, occurring farther north chiefly on shaded ledges arising from the banks of small streams. Most of the liverworts are flattened, skin-like structures, often without distinct stems or leaves. Some of the liverworts are more like mosses in shape. As with mosses, reproduction is by alternation of generations.

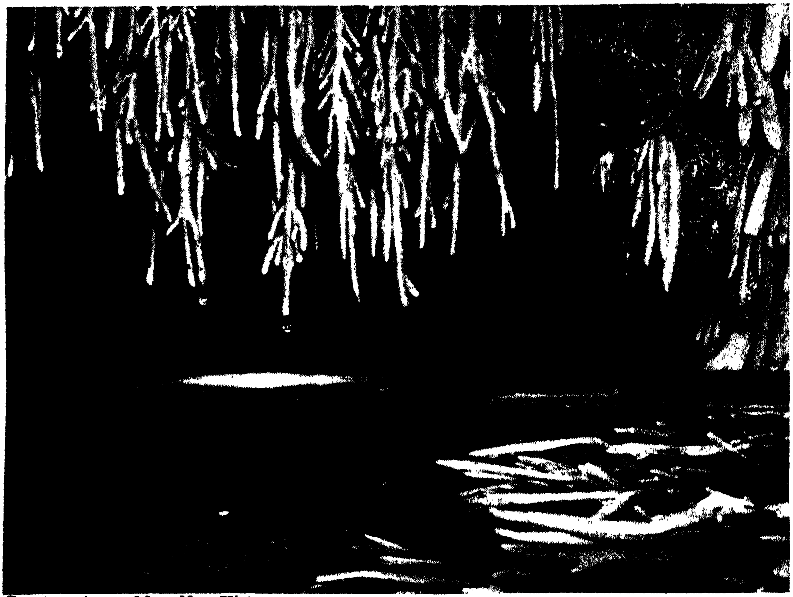
Thallus Plants

The thallus plants are the simplest of all plants in structure. If you live near the seacoast you will find seaweeds, and they are thallus plants with simple and indefinite forms. Many of the other species in this group are even simpler in structure.

Most organisms have their bodies built of small bits of living stuff. Each small bit is called a cell. Many of the thallus plants are, like plants of other groups, formed of masses of cells; but there are many of the very small thallus plants that consist of only single cells. Such plants are, of course, microscopic. Single plants cannot be seen with an unaided eye, a microscope being needed to make them visible. No other plants are as simple as these. By studying the very simple methods of feeding, growth, and reproduction which occur among these plants, the biologist has learned many of the fundamental principles of biology, and in this way has gained an understanding of the more complicated processes of other organisms. For this reason, advanced texts on botany often give considerable space to the various kinds of thallus plants.

Algæ.—The algæ (*alga* in the singular) are thallus plants that contain chlorophyll, the same green material which is found in most of the higher plants. Because it contains chlorophyll, the alga is able to manufacture its own food.

Many of the microscopic, one-celled algæ are so abundant that they give peculiar colors to the ocean. The color of the Red Sea is due to the algæ in it. Smaller, fresh-water forms of algæ may fill slow streams, or they may form green scums of solid, thread-like masses on the surfaces of ponds. They may be responsible for the fishy or other odors of such water. With the death and decay of the microscopic algal material in open reservoirs in the late summer and fall, city water supplies often become very disagreeable in taste. Some tiny forms of algæ cover moist rocks and tree trunks, giving them a greenish color. The undisturbed, uncultivated soil in shaded and moist places often becomes green with a similar coating of plants. The brilliant colors of the formations about the hot springs in the western United States are due to deposits made by the algæ that live even in those places.

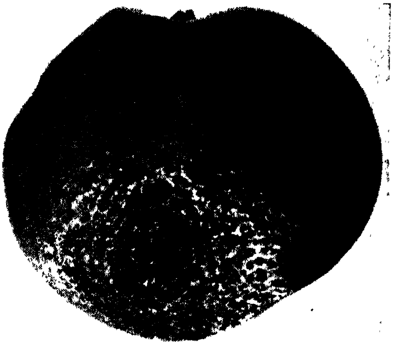


Courtesy Amer. Mus. Nat. Hist.

FIG. 19.—SEAWEEDS ON A ROCKY COAST

Some of the minute algæ that float on the surfaces of fresh and salt waters furnish a considerable amount of food material for animals, contributing foods for fish and even for whales.

The best-known algæ are the larger seaweeds that so often pile up on our ocean coasts. They are built up of masses of many cells. Some of the largest of all plants are the giant kelps, seaweeds of the Pacific area. The "Sargasso Sea" which forms in the Gulf Stream off the southern coasts of North America consists of detached and drifting masses of certain seaweeds. Important chemical elements, including potassium, accumulate in these ocean plants, and seaweeds are therefore considered valuable fertilizers for use on farms. They are also a chief source of an even more valuable element, iodin, which is used in manufacturing processes and in many medicines.



Courtesy U. S. Bur. Plant Industry

FIG. 20.—A FUNGUS RUST ON AN APPLE

Fungi.—The fungi (*fungus* in the singular) are thallus plants that lack chlorophyll. They are, therefore, unable to manufacture their own starches and sugars. All of these plants must live more or less as parasites, stealing their foods from other organisms.

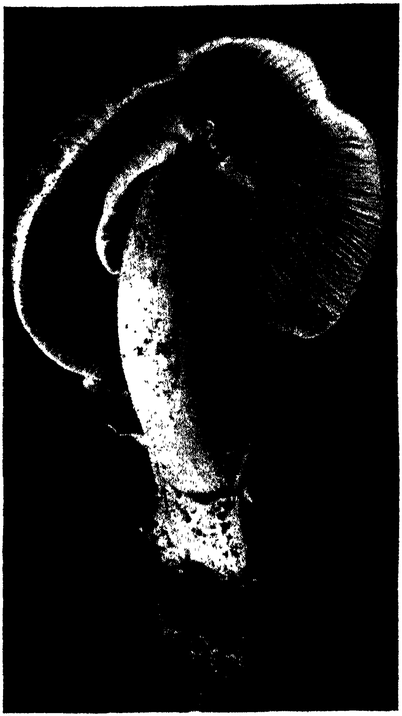
In this group belong the yeasts, molds, and mildews; various crop pests known as blights, rots, smuts, and rusts; and puffballs, woody fungus growths, toadstools, and mushrooms. The larger forms are familiar objects, but most of the fungi are microscopic. These last are nevertheless of tremendous economic importance, causing many millions of dollars of damage to stored foods and to agricultural and forest crops each year. Perhaps you have not realized that the diseased conditions of so many growing crops were due to the fungi living on them.

If you have lived on a farm, you may know the potato blight, or potato wart, or the dry rot of potatoes, the downy mildew of grapevines, corn smut, wheat rust (famous because it completes part of its life history by living on wild barberry bushes), the leaf-spot diseases of apples, cherries, quinces, and strawberries, the brown rot of peaches and plums, or the peach leaf-curl. All of these are diseased conditions produced by fungi.

If you have tried to grow a small garden or shrubs or trees, you may know such fungus-produced diseases as the mildews that turn white the leaves of roses, lilacs, and other plants; or the bean anthracnose that produces the black spots so common on the pods of string beans. All of us are familiar with such fungi as the common mold which forms on bread kept in a damp place; the other molds and mildews that form on so many other foods, on old shoes stored in damp places, or on the earthen floors of damp cellars; or with the black rot of tomatoes. The white-pine blister rust causes considerable damage to pine forests in this country. The chestnut blight disease has largely exterminated the chestnut tree in parts of the eastern United States. Some of the fungi attack animals, causing the common fungus diseases of such forms as goldfish, the death of many flies and other insects, and even the familiar "ring-worm" disease and "athlete's foot" of the human.

The yeasts are also microscopic fungi, best known to us in the compressed masses in which they are sold on the market. Yeasts are responsible for the changes which occur in the sugars of fruit juices, producing the alcohol which makes these juices into wines or other intoxicating liquors. This process, called fermentation, is one we shall wish to consider at greater length in a later part of our study. Different kinds of yeasts are responsible for the different flavors of the wines of different regions. When sugar and yeast are added to warm bread dough, fermentation occurs, and the gases given off by this process are responsible for the rising of the bread. Other products of the fermentation in such dough are responsible for the fact that bread made with yeast is very different in taste from the "unleavened" bread usually baked by more primitive people.

While many of the fungi mentioned above are so small that we can never hope to see them except under a microscope, the larger fungi, including the mushrooms, toadstools, puffballs, and other woody species are fairly familiar to all of us. There are thousands of species of larger fungi, most of them to be sought in damp places. It is interesting to make a collection of the more woody types, many of which may easily be preserved as dry specimens which will lose little of their brilliance of color and peculiarity of form.



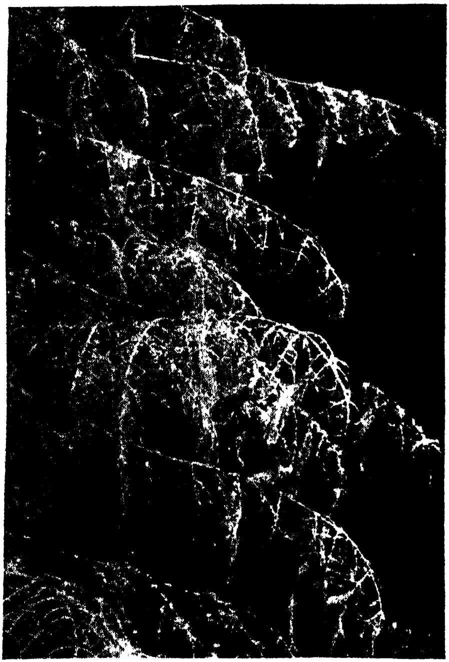
Courtesy U. S. Bureau Plant Industry

FIG. 21.—THE DEATH-CUP

A poisonous fungus, to be recognized by its generally white color, "gills" which do not quite reach the central stem, "veil" hanging from the upper part of the stem, and swollen "cup" at the base.

Edible species of larger fungi are popularly called mushrooms, and the poisonous species, toadstools; but the separation of mushrooms and toadstools is not correct scientifically. In our scientific classifications many a group of fungus plants contains both edible and deadly species. Indeed, it should be said that there is no single test for distinguishing a poisonous fungus from an edible one, even though statements to the contrary often appear in print. You had better leave the gathering of mushrooms to those who are experts in distinguishing the edible forms. One of our common fungi, the death-cup, is even dangerous to touch; and its poison in a wound or in one's stomach would be as dangerous as rattlesnake poison; so you should learn from the accompanying illustration how to recognize this species.

Lichens.—Although we have described the two groups which we said were thallus plants, we shall have to consider some other formations. These are the lichens (pronounced *lī'-kens*). They are not simple plants, but growths containing algæ and fungi combined in such intimate ways that the separate plants cannot be seen with the naked eye. The alga, with its chlorophyll, manufactures the food for both plants; the fungus, with its larger growth, supports the alga and stores water for it. Both plants profit by the association.

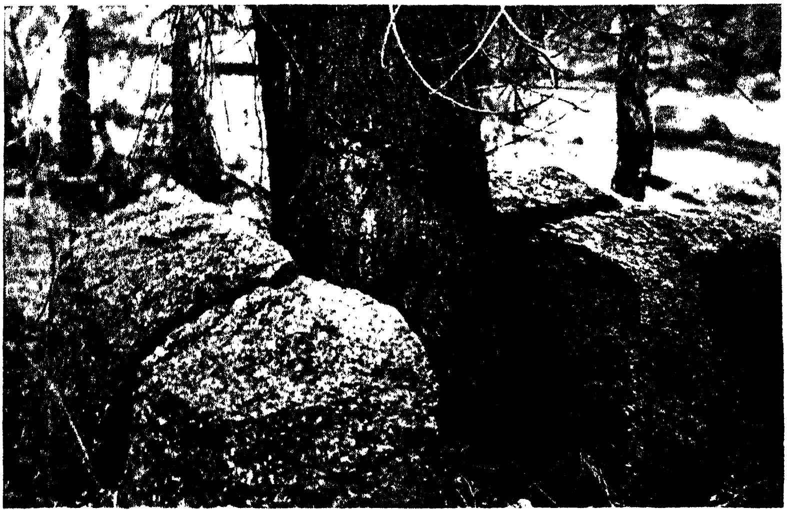


Courtesy Prof. Fink and U. S. Nat. Mus.

FIG. 22.—LICHENS

On the dead branches of an evergreen tree.

Lichens are often skin-like, crust-like in form, growing very commonly over the ground, on rocks, and on tree trunks. Some species are much branched, bushy, also growing in mats on the ground or hanging in dense, shreddy masses on the branches of trees. These bushy lichens are often mistaken for mosses, though the resemblance is very superficial, for mosses always have distinct leaves and stems. Lichens are able to exist under unusually severe conditions, and for that reason they are often the only plants to be found in such barren places as burned-over country, high mountains, and the far North. In such places they furnish food for animals. The so-called reindeer moss which forms dense cushions everywhere in northern forests and on the Arctic tundras, is one of the lichens on which larger animals often feed. Arctic explorers have been glad to eat various kinds of lichens, for they are nutritious; but I have made soup of them, and they taste horribly bad.



Courtesy Amer. Mus. Nat. Hist.

FIG. 23.—SUCH WORK IS OFTEN STARTED BY LICHENS

Lichens, tiny as they are, often work damage to whole mountains. They are the first plants to fasten themselves on the bare rocks in mountainous regions. Working down between the tiny grains of a rock, they split them loose and work out crevices. Dust and decayed lichen materials gathering in these crevices furnish soil enough for mosses or other small plants to grow, and in time enough debris accumulates to support perhaps some bush or a tree. The roots of this larger plant work further damage to the rock, and in the winter the water that freezes in the crack expands until the boulder or the bedrock itself is split to pieces. Much of such frost action, working gigantic changes in northern mountain country, is started by these tiny plants called lichens.

SUMMARY

1. Taxonomy is the biologic science in which organisms are named and classified and their relationships shown.

2. At the outset, in our exploration of the living world, we shall want to learn the names and some of the characteristics of the main groups of plants.

3. Plants are usually to be distinguished from animals by their combination of four characters: chlorophyll, which makes it possible for them to manufacture their own starch and sugar foods; cellulose (which forms wood); their inability to move rapidly; their inability to respond as rapidly as animals.

4. The classification of the plant kingdom, now arranged in the usual scientific order, is as follows:

Group 1. **Thallus Plants.**—Without distinct leaves, stems, or roots. Important for biologic study.

Algæ.—Simple structures, with chlorophyll. Seaweeds, pond scums, in fresh and salt water, and on damp earth.

Fungi.—Simple structures without chlorophyll. Yeasts, molds, mildews, blights, rots, smuts, rusts, puffballs, mushrooms, toadstools. Of great economic importance.

Lichens.—Algæ and fungi growing together, the alga manufacturing the food, the fungus supporting the alga and storing water. The first kind of growth in mountain country, starting destruction of rocks.

Group 2. **Mosses and Liverworts.**—Green and leafy plants alternating with less conspicuous, spore-bearing generations.

Mosses.—Having stems and leaves, but no true roots. Peat moss important.

Liverworts.—Often flattened and skin-like.

Group 3. **Ferns and Allies.**—With leaves, stems, and roots, and with veins for carrying sap; with alternation of generations, with the spore-bearing generation the most prominent. Common plants in the Coal Age, now on the road to extinction.

Group 4. **Seed Plants.**—With leaves, stems, and roots, and with veins for carrying sap; with flowers and seeds. The conspicuous plants.

Ancient Seed Plants.—Seeds usually in cones; leaves narrow, usually evergreen. Cycads, conifers, pine, spruce, fir, etc. Most important timber source.

Monocotyledons.—With one cotyledon; woody bundles scattered throughout the stem; the bundles forming parallel veins in the leaves. Flower parts usually in 3's or 6's. Palms, yuccas, lilies, grasses, etc., the grasses the chief source of cereal foods.

Dicotyledons.—With two cotyledons; woody bundles in a ring in the stem, the bundles forming net veins in the leaves. Flower parts usually in 4's or 5's. Common flowering plants.

DEFINE

The following biological terms have been used for the first time in these introductory chapters. They were defined in the chapter itself, and you will find precise definitions, with indications of pronunciations, in the **Glossary** near the end of this book. In preparing your lesson you should make sure that you have learned the meanings of these.

Biology
Biologist
Organism
Scientist
Species
Taxonomy
Taxonomist
Classification
Plant
Animal
Chlorophyll
Cellulose
Seed plant
Seed
Ancient seed plants
Conifer
Monocotyledon
Dicotyledon
Cotyledon
Fern
Fern allies
Spore
Prothallium
Alternation of generations
Moss
Liverwort
Peat
Coal
Coal Age
Thallus plant
Cell
Algæ
Fungi
Parasite
Fermentation
Lichen

PROBLEMS

1. What four things in this chapter surprised you most? In each case, why did you not know these things before?

2. Prepare a list of as many kinds of algæ as you know by name. Be prepared to tell something about each kind.

3. Do the same for the fungi.

4. Do the same for the mosses and liverworts.

5. Do the same for the ferns and fern allies.

6. Do the same for the conifers.

7. Prepare a list of 15 kinds of monocotyledons.

8. Prepare a list of 25 kinds of dicotyledons.

9. Name some plants that are of economic importance in each of the main groups of plants. Which group has the fewest? Which has the most?

10. Name the groups of plants that have ever grown indoors in your house.

11. Classify the plants shown in this book in 100 of the pictures which include plants (and which are outside of the present chapter). Keep a careful record. Explain your results. Do the most conspicuous plants belong to the group which contains the most species?

12. Which do you think is the most important of the various contributions made by plants to human welfare?

13. What are the chief differences between alternation of generations in a moss and alternation of generations in a fern?

14. Which generation in the fern provides the better food factory? Which provides the better means of distribution?

15. Which generation in the moss provides the better food factory? Which provides the better means of distribution?

16. Look ahead in this book, and see if you can find records of animals that have an alternation of generations.

17. Why do mosses and ferns furnish so little of our human food?

18. Which groups of plants furnish our fuel?

19. Name some plants that lack chlorophyll.

20. Name some plants that lack one or more of the other characters which are usually found in plants.

CHAPTER III

ANIMAL GROUPS[1]

Most animals lack the green chlorophyll and the wood-forming cellulose found in plants. Animals, therefore, have to depend on plants, directly or indirectly, for their foods. Most animals move about more freely than plants and are more easily affected by ("more sensitive to") such things as sound, light, temperature changes, etc. These characters are not found in all species of animals, but they occur among most of the species that are placed in the animal kingdom.

We shall consider 10 phyla and some of the classes of the animals in the same way that we have already considered the main groups of the plants. In this case, however, we shall follow the more usual order and consider the simplest animals first.

Protozoa

The name protozoa means *first animals,* for they are not only very simple in structure, but they are also believed to be most like the first animals that ever existed.

Practically all the protozoa are microscopic and invisible to the naked eye. Protozoa are active only in moist places, and they are most abundant in fresh and salt water. Drinking water that has not been chemically treated usually contains many protozoa. If their surroundings become dry some species shrivel up and develop hard coats, but they do not then die. They may blow about through the air until they reach other favorable locations in which to become active again. This explains why dried grass, soaked in water, will in time breed numbers of protozoa.

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[1] TEACHING NOTE.—This chapter is necessarily long, and it will require extra time for thorough study.

Like many of the thallus plants, these animals consist of only single cells. They are relatively simple, soft, jelly-like drops of living stuff. Some protozoa have shells composed of lime or other mineral materials. When these shells are deposited at the bottoms of ponds or of oceans after the animals die, they give rise to great beds of ooze, and these become solid in the course of time and form one of the common kinds of limestone rock. Wherever this limestone occurs, it is proof that the region was covered, at some remote age, with ocean waters which supported endless numbers of these animals.

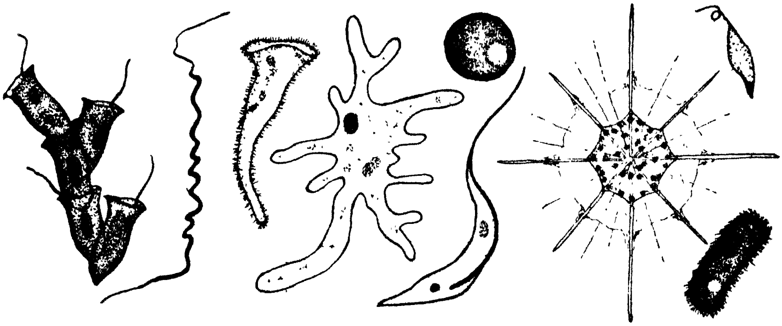

FIG. 24.—SOME PROTOZOA, MUCH MAGNIFIED

Every one of the physiologic processes of a protozoon must be performed by its single cell. As with the simple algæ, these processes are comparatively simple and therefore easily understood. Biologists have therefore studied these animals extensively, finding thereby explanations for many of the more complicated things we observe about higher animals.

Some protozoa live in other animals and plants. Many of these do no harm. Certain of them, however, are the germs that cause such important diseases as malaria, African sleeping sickness, and Texas cattle fever.

Sponges[1]

Even though most people do not realize it, a bath sponge is the skeleton of an animal. The animal itself was soft, jelly-like, covering the harder structures. The skeleton is composed of tangles of small, horny fibers which may be squeezed, as in the bath sponge; or of glassy or limy materials in other sponges.

Sponges are largely marine (salt-water) animals, occurring in numbers in the warmer oceans. A very few species of relatively small size occur in fresh waters, attached to posts or to other dead stuff.

A mass of sponge material can hardly be thought of as a single animal, nor yet as a cluster of animals. It is a great mass of animal cells which work more or less as one organism as long as they stay together, but which may break up into any number of living pieces. This is very different from conditions found among most higher animals. A sponge is unable to move about, remaining wherever it is attached, drawing in water through pores in the side walls, getting whatever food happens to come with the water, and continually casting out waste materials through the large central cavity of the colony.

Polyps and Medusæ[2]

This is again a group of mostly salt-water forms, including the jelly-fish, sea anemones, and corals. These animals constitute a considerable part of the life of the shallower parts of the ocean, of the surfaces of the open seas, and of the "between-tides" (that part of the shore which is covered at high tide but exposed at low tide). Along the Maine Coast I have travelled for hours among small jelly-fish that continually crowded about our boat.

If you live far away from the ocean, you may not be acquainted with any of these animals, for only a very few of them are known from fresh-water streams and lakes.

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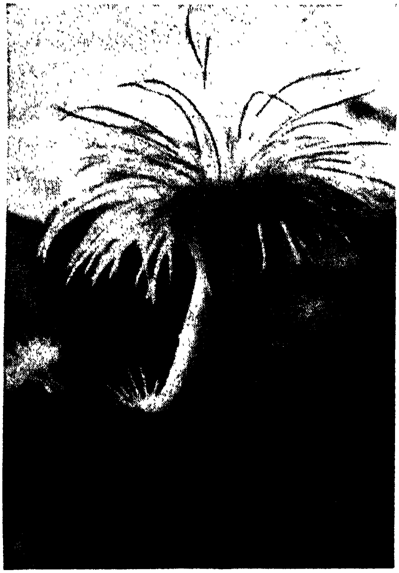
[1] The Latin name is *Porifera.*

[2] *Cœlenterata.*

Polyps and medusæ are of simple structure. They are simple bags of living material each with a single, central cavity through which the food materials, wastes, and reproductive cells are carried in or out by the sea water. By means of thread-like tentacles equipped with stings these organisms capture and kill rather large animals for food.

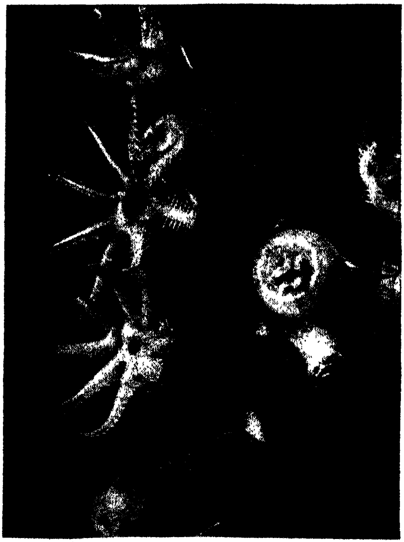


Courtesy Nature Magazine

FIG. 25.—A SEA ANEMONE
One of the group of polyp animals.

Reproduction in this phylum is often connected with an alternation of generations as remarkable as that which occurs among the mosses and ferns. The forms known as polyps give rise to the medusæ, and the medusæ may produce polyps in turn.

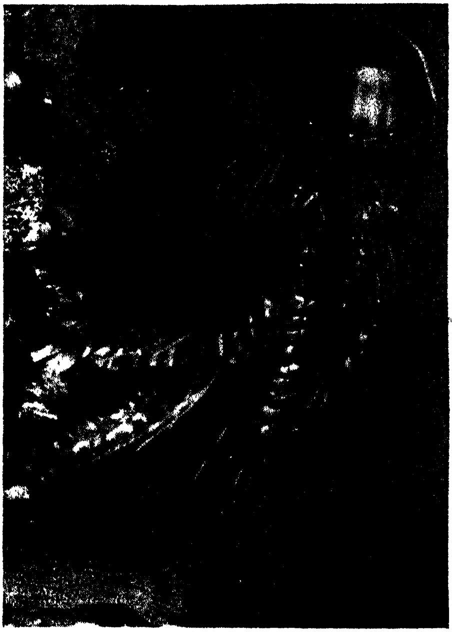
A polyp has the shape of an elongated bottle with its opening at the top. Each polyp may be only an eighth of an inch in length, but the branched and bushy colonies



Courtesy Amer. Mus. Nat. Hist.

FIG. 26.—POLYPS

of these animals, often mistaken for sea plants, may extend for yards over the rocks or seaweeds to which they are solidly attached. Polyps reproduce asexually, which means they do not have eggs. Their offspring may be other polyps like themselves, but among the forms that have alternation of generations the offspring of the polyps will be medusæ.

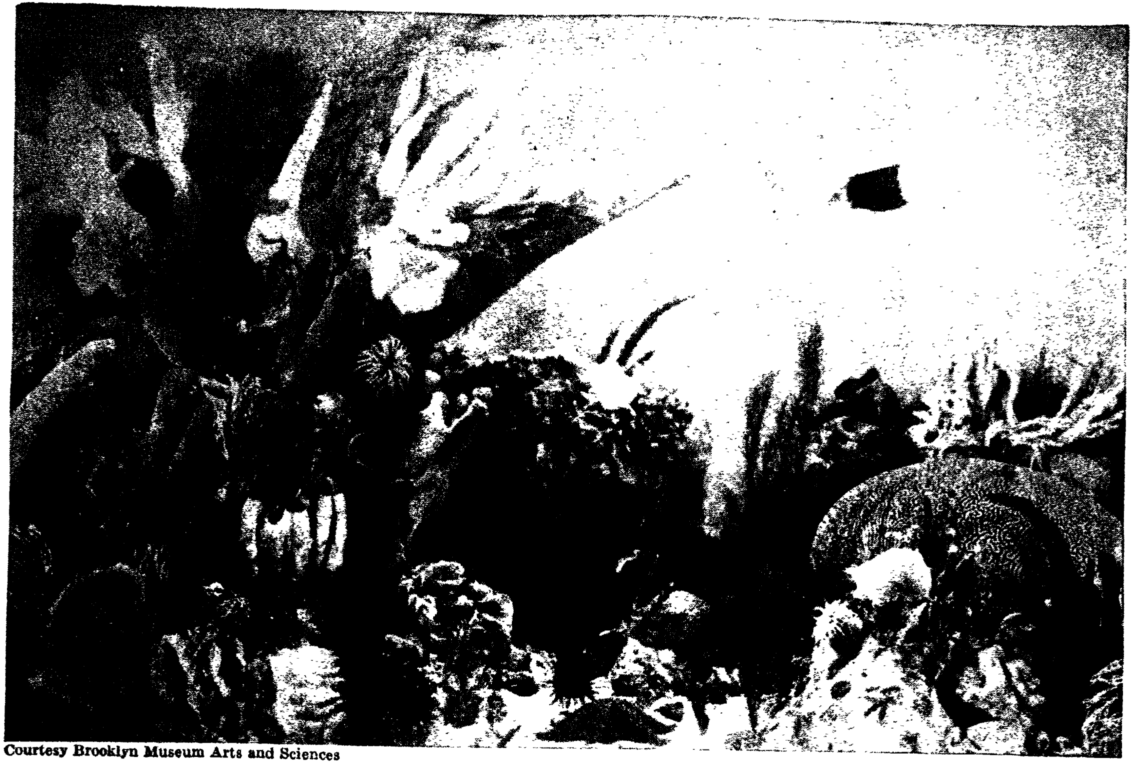


Courtesy Amer. Mus. Nat. Hist.

FIG. 27.—A JELLY-FISH

Medusæ are more like inverted cups with their openings underneath. Jelly-fish are medusæ. They move freely by contracting and expanding, and by floating with the waves and tides. They are delicate, filmy creatures, often beautifully colored. Most of them are small, but some measure over a foot in diameter. They reproduce sexually, with eggs, and their offspring may be medusæ like themselves, but in many species the medusæ give rise to polyps! Though a medusa is so different from a polyp, it is often nothing more than another generation of the polyp. Although we found alternation of generations common enough among the plants, it is a rare thing in the animal world outside of this phylum of polyps and medusæ.

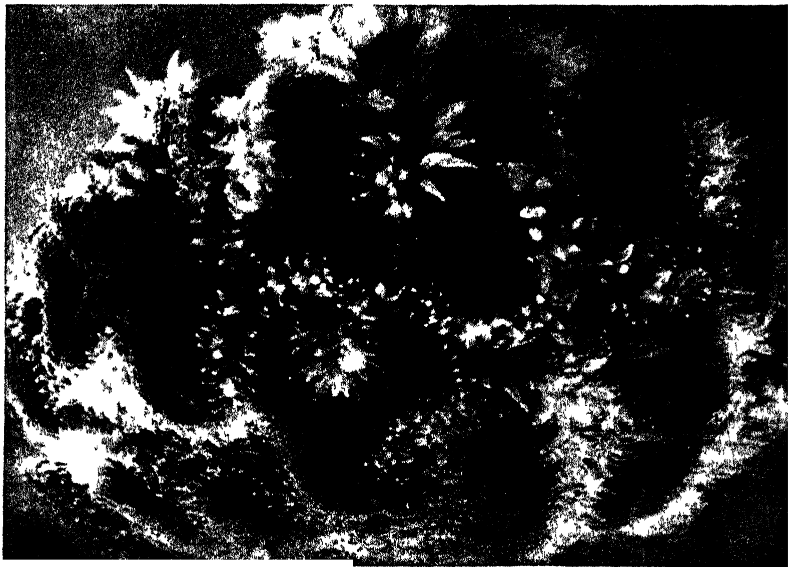
The corals, also belonging to this phylum of animals, have hard skeletons that remain long after the living creatures are dead. All the corals are marine, living in great colonies in the warmer oceans. They grow mostly on the outer sides of the



Courtesy Brooklyn Museum Arts and Sciences

FIG. 28.—PART OF A CORAL REEF IN THE BAHAMAS

reefs where the breaking waves supply plenty of oxygen, and so a reef grows outwardly, often circularly. Wave action piles broken coral above the sea level, and islands are formed. The southern tip of Florida and many of the South Sea Islands originated as coral reefs that have been built up above the surface of the ocean.



Courtesy T W Vaughan and Smithsonian Inst

FIG. 29.—A LIVING CORAL

Flatworms[1]

There are three main groups of worms. The flatworms have flat, ribbon-shaped bodies; the roundworms have rounded, tubular bodies without segmentation; and the segmented worms have their bodies divided into distinct rings or segments.

Some of the flatworms live in fresh water or on moist land. Others are abundant in the ocean. Small, dark-colored forms, a half inch or less in length, are often found creeping slowly on brook bottoms or in springs, or swimming with wavy body motions. They are easily collected to watch in the laboratory. These forms have eyes which are merely colored spots which distinguish light from dark, but they cannot see much else.

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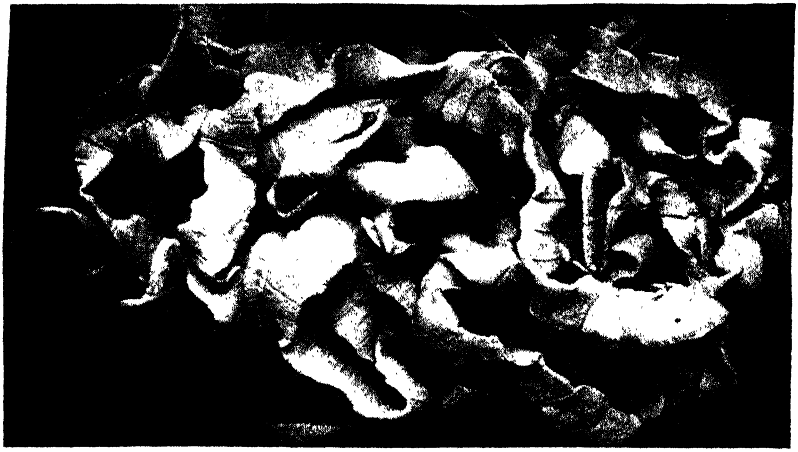
[1] *Platyhelminthes.*

Most of the flatworms are parasites, living upon or within other animals. The creatures on which the parasites live are known as their *hosts*. Typical of all parasites, these flatworms are very simple in structure. Often they have no digestive tracts, absorbing their food directly through their skins from the animals in which they live. Special sense organs are almost entirely lacking, for the parasites have little need of such things inside the bodies of their hosts. Hooks or other structures may attach the worm to its host.



Courtesy U. S. Bur. Animal Industry

FIG. 30.—A TAPEWORM
One kind of flatworm.

The liver fluke, responsible for the death of millions of sheep, is a flatworm which lives at first in a small water snail. Later it leaves the snail and crawls out of the pond onto the grass where the sheep are feeding. Entering the sheep's digestive tract, the fluke passes into the liver of its host, and there, when it becomes about the size and shape of a pumpkin seed, causes the death of the sheep. The eggs of the worm are scattered in the pastures, to reinfect snails.

Tapeworms are flatworms whose bodies are divided into many segments. If the rest of the body is lost, the very small head is able to regenerate a whole worm. Tapeworms have been known to be ten or twelve yards in length. They inhabit the digestive tracts of many animals, being not uncommon in man. Many of these worms have two hosts in a lifetime. The first host may be a plant-feeding animal which eats the plants on which the worm eggs are found. The second host is often a meat-eater, feeding on the infected first host. Thus a worm may pass from a snail to a duck, from a rabbit to a dog, from fish or beef or pork to man. The thorough cooking of food guards the human against most infections of flatworms, as well as of roundworms and other parasites which are only too common in meats. Cat and dog fleas are sometimes loaded with parasites, and children who handle or kiss the household pet are likely to swallow the fleas accidentally and become infested with tapeworms.

Roundworms[1]

These worms are round and cylindrical, often like earthworms in shape; but unlike earthworms they do not have their bodies divided into segments.

The only roundworm that is commonly known is the so-called horse-hair snake of watering troughs. Nevertheless the roundworms constitute one of the very large phyla of animals, unfamiliar only because they are ordinarily very small, and because the parasitic forms are usually hidden within their hosts. One authority estimates that the roundworms living in the earth of many a ten-acre field are so abundant that, arranged in single file, they would form a procession long enough to reach around the world. A single animal like a horse has been known to be infested with several million of these parasites. It is a rare cat's intestine that does not contain a dozen or more worms an inch or two in length. One species of roundworm causes the gapes in chickens. These worms are not unknown in man, even large species being common in children in regions where sanitary conditions are not good.

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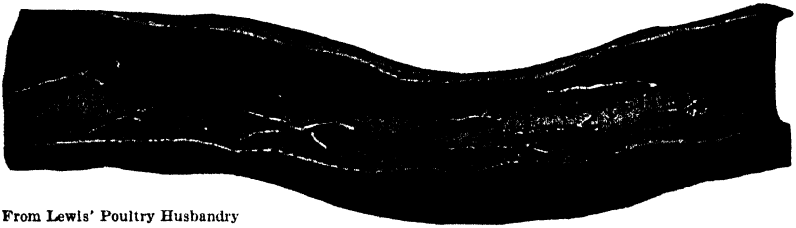
[1] *Nemathelminthes.*

Many of these worms are responsible for serious diseases. Pork that is not well cooked may pass on the trichina worm to man; going barefooted over soil infested with hookworms is the chief means of infection with that disease in the Southeastern United States. Some roundworms are accidentally swallowed with insects, or in drinking water. Mosquitoes are responsible for passing other species into the man whose blood they suck. Many serious plant diseases are caused by these worms, and the damage they do annually to food crops like potatoes, carrots, and sugar beets is very great. Often the parasites cause large, abnormal swellings, which we call *galls*, on plants.



From Lewis' Poultry Husbandry

FIG. 31.—ROUNDWORMS (GAPEWORMS) IN THE WINDPIPE OF A YOUNG CHICK

Segmented Worms[1]

The familiar earthworms are typical segmented worms, although many other forms also belong in this group. Among these are the clam worms and many kinds of marine worms, some of which are very unusual creatures in shape, enclosed

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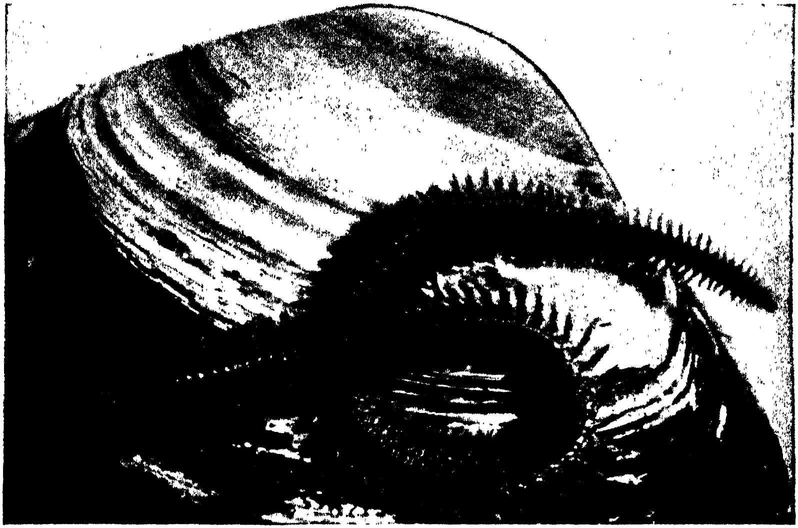
[1] *Annelida* or *Annulata*.

sometimes in hard shells, and sometimes reaching lengths of several feet. Leeches, which resemble flatworms, are really segmented worms, as their internal structures and early stages show. Leeches are often parasitic, and as "bloodsuckers" they are familiar enough to those who have gone swimming in fresh-water lakes and ponds.



Courtesy Nature Magazine

FIG. 32.—CLAM WORM
A marine, segmented worm.

These worms (except the leeches) have bodies which are divided into many similar segments. They usually have legs which are bristle- or lobe-like and unjointed. The internal structure is much more complicated than that of any of the worms yet considered.

Echinoderms[1]

The scientific name echinoderm is the only good one which we have for this group. The name comes from Greek words meaning "spiny skins," referring to the most distinctive characteristic of these animals.

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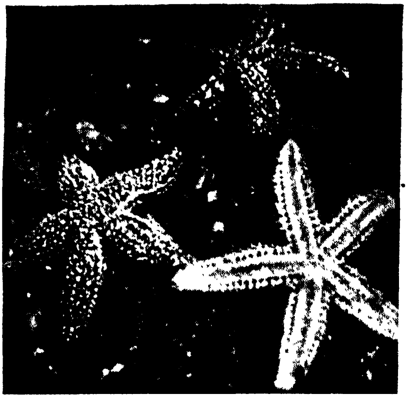
[1] *Echinodermata.*

The echinoderms are very different from worms, and indeed from any other animals. All of the species are marine; many of them are confined to the between-tides and the shallower areas off shore. Starfish, sea urchins, sea cucumbers, and sand dollars are members of this group. All of these occur rather commonly on the coasts of the United States.



Courtesy Nature Magazine

FIG. 33.—STARFISH

The best-known echinoderm is the starfish, with its body divided into five distinct "arms." In spite of its thick, spiny shell which becomes very hard in dead specimens, the living starfish is flexible, and walks rather rapidly by doubling up, bringing the tips of its arms together and extending them—looking not unlike a large measuring worm looping along. Starfish feed on other animals, including crabs, oysters, and clams.

A clam, overtaken by a starfish, shuts up "as tight as a clam," pulling its shells together with its very strong muscles. By means of sucker-like processes on its arms, the echinoderm fastens onto the opposite shells of its victim and waits, perhaps for hours, until the clam's muscles tire and, bit by bit, let the shells open. Then the starfish, if you please, just turns its stomach inside out, pushes it through its own mouth, surrounds the softer parts of the clam, and digests them. In a similar fashion starfish do much economic damage to oyster beds.

If an arm be broken off a starfish, a new one will grow again, or **regenerate** as we say. Regeneration in man and the higher animals is confined to the healing of relatively slight wounds, but many of the lower animals, and even forms as high as the cockroach, can regenerate whole parts of their bodies.

The echinoderms are very different from all other animals. Fossils show that many species became extinct ages ago.

Courtesy Amer. Mus. Nat. Hist.

FIG. 34.—TYPICAL CRUSTACEANS

A lobster capturing a crab.

Arthropods[1]

The word *arthropod* is worth learning. It is the only good name for the largest of all the animal phyla. Crabs, lobsters, thousand-leggers, scorpions, spiders, ticks, and the great array of insects are familiar arthropods.

All arthropods have segmented bodies and jointed legs. Their skins form remarkably hard, external skeletons (think of a crayfish or of a beetle) which wonderfully protect the animals against injury. These skeletons provide further protection because they contain a peculiarly indestructible substance called *chitin*. Chitin may be placed in most of the strong acids without being dissolved.

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[1] *Arthropoda.*

We shall consider only 6 of the dozen or more classes of the arthropods.

CLASS 1. **Crustacea.**—These have two pairs of antennæ ("feelers") and five or more pairs of legs, and the body is divided into two major parts (*cephalothorax* and *abdomen*). Most of these animals live in shallow salt water or in the between-tides. These are the lobsters, crabs, shrimps, barnacles, and many smaller forms. A few species occur in fresh waters. Thus the crayfish (also called crawfish and crawdad) and smaller, less familiar, shrimp-like forms are often abundant on the leaf-covered, muck bottoms of brooks and ponds. Sowbugs and pillbugs are crustacea found in moist places on the land, under old boards or in cellars (where they usually do no harm). When touched the pillbugs roll up into tight, hard "pills." Crustacea feed upon either plant or animal materials, often doing general scavenger work. In turn the smaller crustacea serve as food for fish, and some forms are important as human foods.

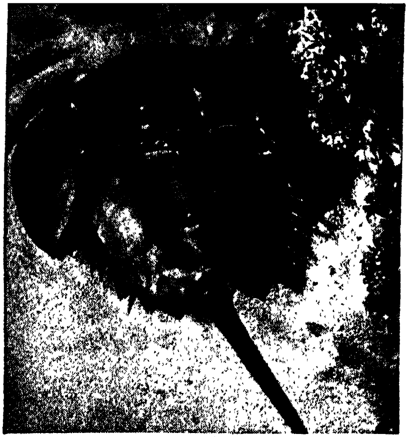
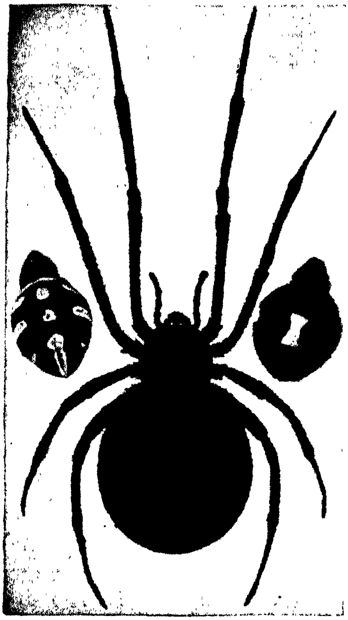

Courtesy Amer. Mus. Nat. Hist.

FIG. 35.—A HORSESHOE CRAB

CLASS 2. **Horseshoe Crabs (or King Crabs).**—They are not the crustacea which they superficially appear to be. They have no antennæ. They are very common in shallow sea waters along the whole Atlantic Coast of the United States, but there is only one species in North America, while only four others are known from other parts of the world. Nevertheless, the fossil records show us that the group thrived millions of years ago. Should you meet a horseshoe crab, regard it with respect, for it is one of the last survivors of a group that is nearing complete extinction.

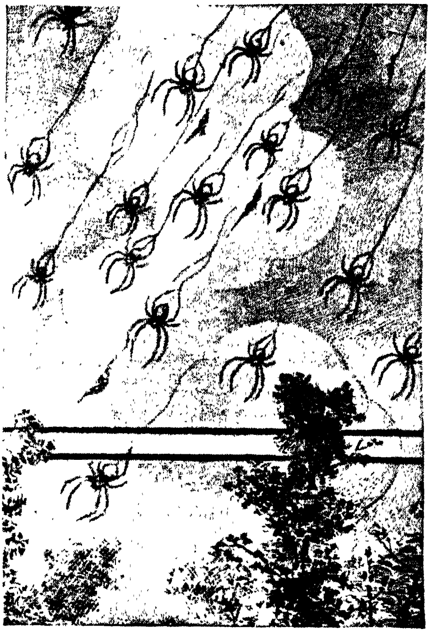
CLASS 3. **Arachnids.**—These are spiders, mites, ticks, chiggers, scorpions, and daddy-long-legs (also called grandfather-gray-beards, or harvest-men). They have bodies with two parts (cephalothorax and abdomen) and four pairs of legs. Some spiders have a pair of mouth-parts so large that you might mistake them for a fifth pair of legs. Arachnids are not insects even though the two groups resemble each other.



After Comstock, Spider Book

FIG. 36.—BLACK WIDOW SPIDERS

To be recognized by its coal-black color and yellow-red markings on the under surface. Male abdomen to left, female to right.

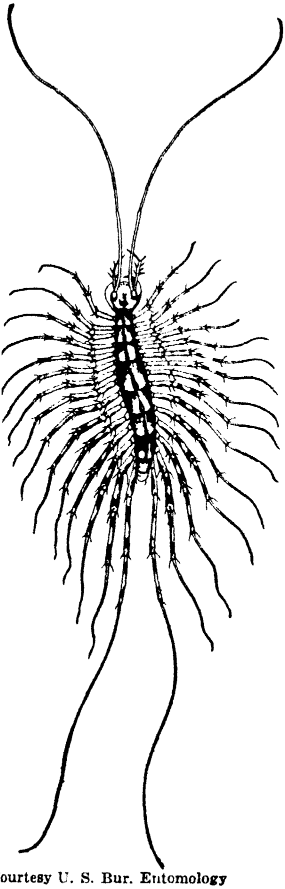


After Fabre. Courtesy Dodd, Mead & Co.

FIG. 37.—YOUNG WOLF SPIDERS IN FLIGHT

The adults commonly live in holes in the ground.

All of the arachnids are land inhabitants with the exception of a very few species of sea spiders and some fresh-water forms. Scorpions are poisonous, often seriously so; they are mostly confined to more southern parts of the country. Mites, chiggers, and ticks are usually parasites, living on or beneath the skin of men, cattle, and other animals. Ticks distribute the organisms of several diseases, such as those of the Rocky Mountain spotted fever of man and of cattle, and of the Texas cattle fever.



Courtesy U. S. Bur. Entomology

FIG. 38.—A COMMON CENTIPEDE

Spiders are largely insect feeders, and therefore beneficial to man. Most spiders are equipped with poison glands, but all of them except the southern tarantulas and the more widespread species shown in the illustration (Figure 36) can be safely taken into one's hand. Spider **silk** is of considerable interest. Considering its size it is the strongest cable known to man. It forms bridges and ropes on which the creatures travel; it furnishes houses for protection, nurseries, and beds and blankets for the eggs and the babies, traps for catching food, and balloons for flight. Have you ever seen young spiders flying? They may be found lined up on a fence rail, putting out tufts of threads, holding tightly upon tiptoes until there is enough silk and a strong wind to carry them off over the countryside.

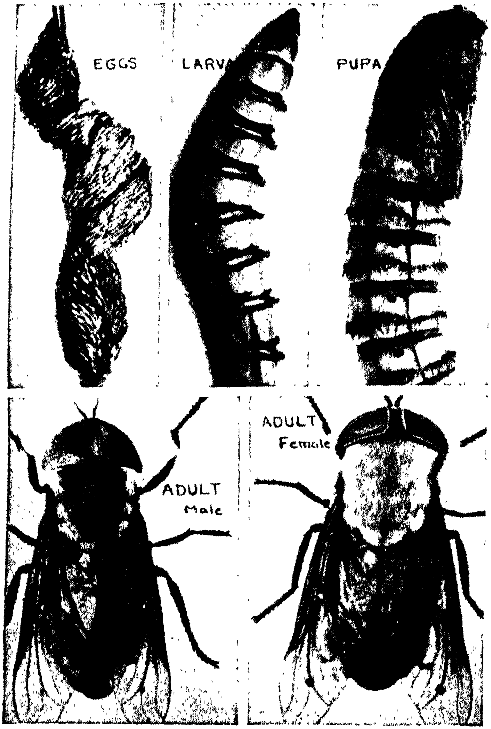
Class 4. **Millipeds.**—These, more popularly known as thousand-leggers, are slender, worm-like, many-legged creatures found under cover, in rubbish, or in earth. They have two pairs of legs to each segment, a total of two hundred or more—not the supposed thousand, but enough! The antennæ are inconspicuous. None of these animals is poisonous nor harmful in any way unless it feeds, as it occasionally does, upon the roots of plants.

Class 5. **Centipedes.**—These have only one pair of legs to a segment, and a pair of conspicuous antennæ. They live on the land, particularly under boards or other cover. If you see what appears to be a very lively tangle of hairs scurrying away in your cellar, you may know it is a centipede with its twenty or thirty legs a-flying. The front legs are poison jaws. Many of the species of the South and West can inflict serious wounds. No very dangerous species live in the northeastern part of the country. Centipedes are insect-feeders, and in that respect are beneficial.

Class 6. **Insects.**—Insects have three pairs of legs, one pair of antennæ, and three parts to their bodies (head, thorax, and abdomen). These are grasshoppers, beetles, bugs, ants, bees, wasps, roaches, lice, dragonflies, butterflies, moths, and others—a couple of million species or more. Five-sixths of all the known species of animals in the world belong to this single class. You must give up any idea that the classes of animals are of about equal size, for most animals, both kinds and individuals, are insects.

Insects and other arthropods have such hard shells that they cannot grow quite as other organisms grow. They must do their growing inside their skins, and when there is no longer room for that, they split off their skins *(molt)*, appear in new, softer skins, and grow at an astounding rate for half an hour or so until the new shell in turn becomes too hard; and then they settle down to one size for a few weeks or months until the next molt occurs. The series of changes through which growth is accomplished is known as the *metamorphosis* of the arthropod.

Some insects (roaches, grasshoppers, bugs) do not look very different from molt to molt, except that they become larger and develop wings. These insects are said to have a *direct metamorphosis*. But most insects change considerably, appearing in three very distinct styles of clothing in a lifetime. Such growth is known as *indirect metamorphosis*. The three stages are called the *larva*, *pupa*, and *adult*. A moth larva (caterpillar) becomes a pupa (often inside a silken cocoon) and finally a winged adult. The larvæ of flies are commonly called maggots; those of beetles are called grubs. Adult insects never molt, and therefore never increase in size; small flies are not the young of larger flies, but adults of entirely different species! It will pay you to watch closely the metamorphosis of some moth or butterfly or other insect, to observe its development from its larval to its adult stage.



Courtesy U. S. Bur. Entomology

FIG. 39.—AN INSECT LIFE HISTORY

Horsefly. An instance of indirect metamorphosis.

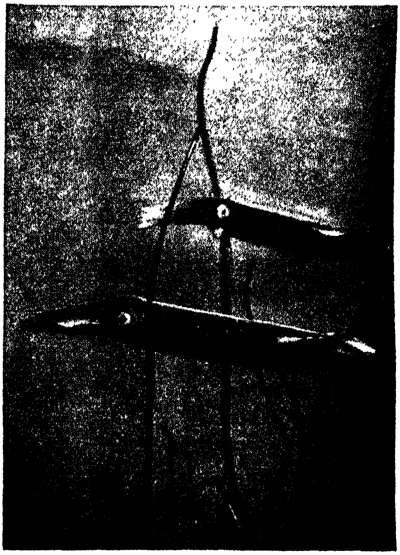
The small sizes of most insects make them inconspicuous. But no one can ignore their work. Tremendous numbers of plants, human food crops and forests, are destroyed by these arthropods. Mosquitoes and other such pests often make life miserable. Many of the most serious disease-producing organisms are distributed by insects. On the other hand, many species are beneficial, doing scavenger duty, or killing some of the harmful insects, or carrying pollen and helping flowers form seeds.

Insects are most interesting things to observe, and *Entomology,* the study of insects, is the chief occupation of many biologists.

Molluscs[1]

The molluscs are soft-bodied animals living, usually, within hard shells which may be single as with a snail or a nautilus, or double as with a clam, oyster, or mussel. Only a few molluscs, such as the squids, the octopuses, and the common, worm-like slugs that leave slimy trails in your cellar and garden, lack visible shells.

Some molluscs live on the land; most of them live in the ocean; but a number are found in fresh water. Each of the innumerable, fine, groove-like tracks on the bottoms of shallow streams or ponds leads to a snail creeping along with its shell atop.



Courtesy Amer. Mus. Nat. Hist.

FIG. 40.—SQUIDS
A kind of marine mollusc.

Molluscs do scavenger duty in our streams and ponds and along the ocean coasts. Clams, oysters, and mussels furnish important human foods. Pearl may be obtained from the linings of mussel shells. The more rounded, more valuable pearls are formed when a pebble or some foreign creature enters a mollusc shell and leads the mollusc to cover the nuisance with a liquid material that soon hardens into pearl.

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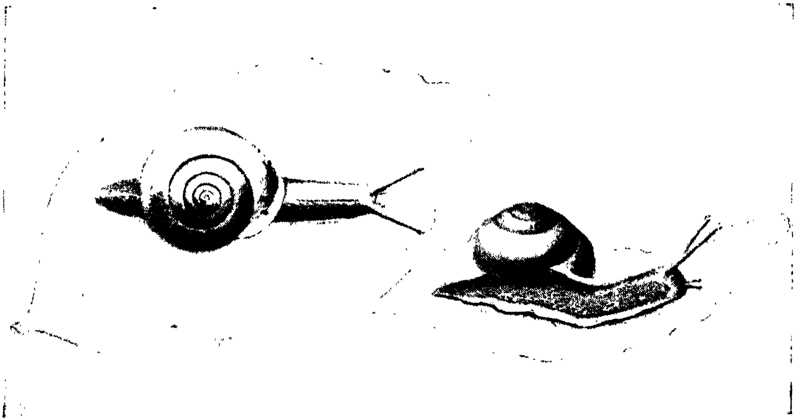
[1] *Mollusca.*

Vertebrates[1]

These are the only creatures that have internal skeletons of true bones. The backbones of these animals are made up of small sections, each of which is called a *vertebra*. The small, drum-shaped vertebræ of salmon are familiar objects in the canned fish. The presence of a back-bone built of vertebræ in all of these animals gives rise to the name of the phylum.



Courtesy N. Y. State Museum

FIG. 41.—LAND SNAILS

CLASS I. **Fish.**—Most fish have scales over their skins and fins for travelling. All fish live in water, either fresh or salt, and there are few ponds or streams or corners of the ocean which do not harbor fish. There are a great many kinds of fish in the world. Besides furnishing quantities of food for man, many fish are important as scavengers and as destroyers of aquatic insects and other small organisms. Fish in a pond or well or stream will keep mosquito larvæ from developing in it. Many fish have interesting feeding or nesting behavior that is worth watching.

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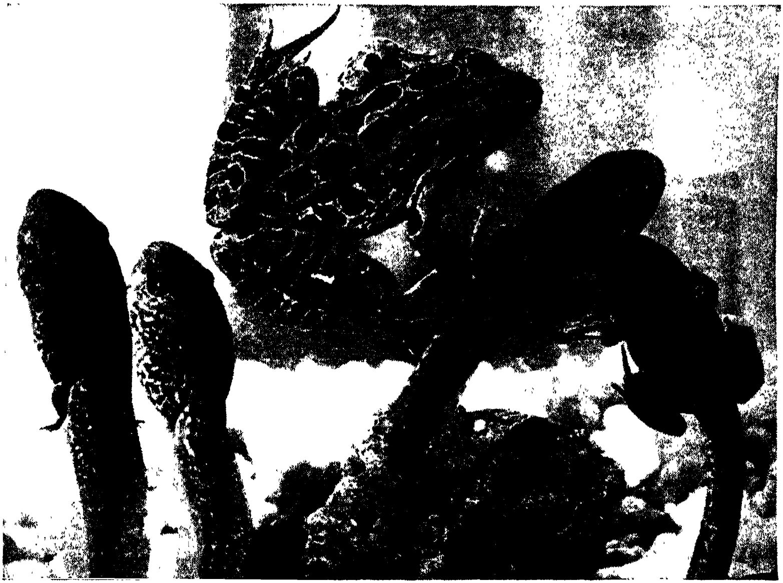
[1] *Vertebrata* of the older classifications; *Chordata* of the new.

CLASS 2. **Amphibia.**—These are the frogs, toads, salamanders, mud-puppies, and newts. They all possess moist or even slimy skins that have no scales. Much of the oxygen which an amphibian uses in respiration is taken directly through this moist skin rather than through its lungs.



Courtesy N. Y. Zoological Society

FIG. 42.—TADPOLES TURNING INTO FROGS

The name *amphibia,* meaning "double inhabitants," refers to the fact that all of these creatures begin life in the water and most of them take to the land when adult. The toad egg that is laid in the pond hatches into an almost worm-like, legless, long-tailed tadpole that has gills for breathing. Tadpoles occur in abundance in old mudholes. Have you ever been curious enough to put some of them into a jar, to bring them indoors, and to watch them turn into toads? They develop hind legs first; front legs follow; the tail gradually disappears, its material being absorbed into the rest of the animal; the whole body shortens; the gill openings close up; lungs are formed; and some fine day, a small but nicely formed toad hops out onto the dry land! Toads usually go through their complete development within a month or two; frogs require from a few months to two or more years.

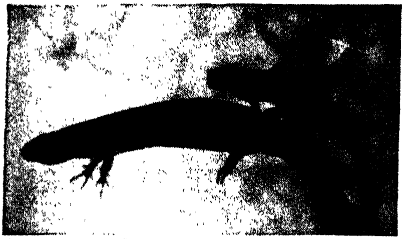

Courtesy N. Y. Zoological Society

FIG. 43.—COMMON WATER NEWTS
These are typical salamanders.

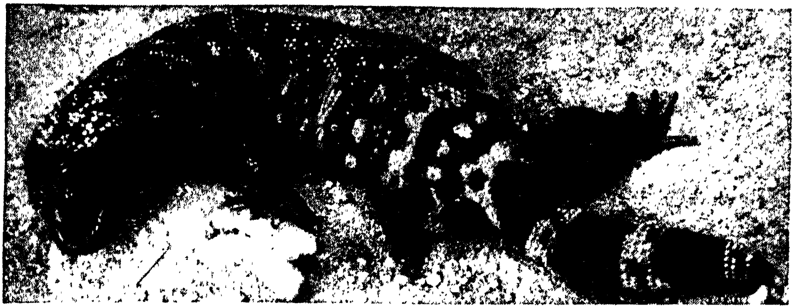
Salamanders are often mistaken for lizards, but lizards have scaly skins. Salamanders are meek and defenseless creatures, and are easily kept in an aquarium.

Amphibia eat a variety of animal foods, including a great many insects. A toad in a garden is a very good friend of man. Frogs' legs, fried in butter, are, in my opinion, poor substitutes for live frogs feeding upon insects!

Class 3. **Reptiles.**—Snakes, lizards, turtles, alligators, and crocodiles are reptiles. They have very dry, very scaly skins. Most of them live on the land, though many of them get along very well in water.

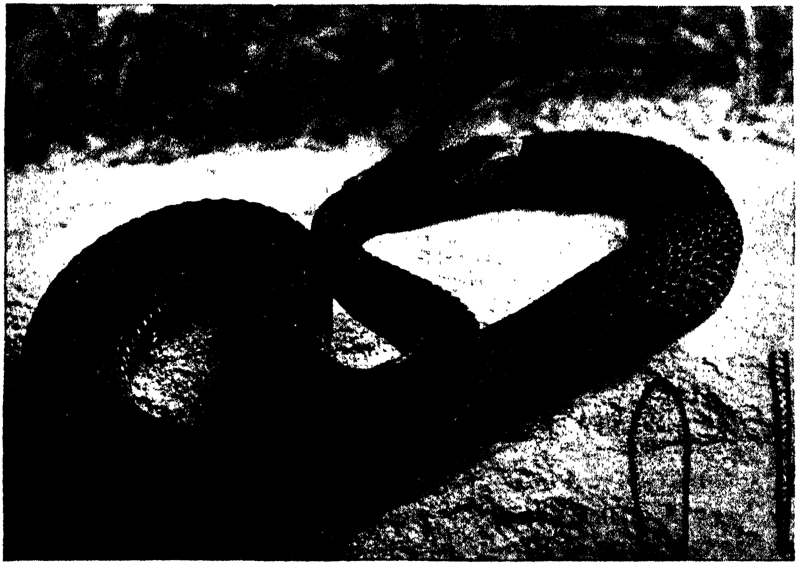
The common prejudice against meeting a reptile is not so well founded as some people would like to believe. Many snakes, lizards, and turtles are harmless and interesting things to watch. In this country the rattlesnakes, the copperheads, the cottonmouth, and the coral snakes are the only very poisonous snakes, although some other less common species of the South and Southwest might cause some trouble.

If a harmless snake bites, its many teeth leave a clean wound almost as continuous as that of a knife. But a poisonous snake leaves the marks of two separated teeth, the hollow fangs which inject the poison from a sac in the roof of the



Courtesy Amer. Mus. Nat. Hist.

FIG. 44.—THE GILA MONSTER, THE POISONOUS LIZARD OF ARIZONA



Courtesy N. Y. Zoological Society

FIG. 45.—A RATTLESNAKE

Compare the head and tail of one of our harmless snakes outlined in the lower corner.

mouth. Careful cutting and sucking of the wound to make it bleed, application of hot water, and a prompt call for a doctor will avoid serious consequences. The automobiles of the United States kill a hundred times as many persons as the poisonous snakes of the same area.

Of the thousands of species of lizards in the world, only a single group is at all poisonous; namely, the genus including the Gila (hē′-la) monster found in a certain small area of Arizona, New Mexico, Nevada, and adjacent Mexico.

Courtesy Ind. State Conservation Dept.

FIG. 46.—BIRDS

Although snakes and turtles often feed upon insects, they are not of great economic importance, for they take only one good meal in several days. Lizards are better insect traps.

CLASS 4. **Birds.**—"Winged creatures with feathers" will always distinguish the birds. No other animals have feathers. The activities of birds as insect and weed-seed destroyers make them of great economic importance. In flight they have no equals; their structures are remarkable; their nesting and feeding and migration behaviors are intensely interesting, their plumages and songs are of great beauty. Therefore: you ought to know each and every species that occurs in your neighborhood—and that, very intimately. Further chapters in this book will be given to the birds.

CLASS 5. **Mammals.**—Mammals have hair, and their young are fed on milk. These are the familiar "four-footed animals." It is incorrect to refer to them as "the animals," for the term animal applies to any organism which is not a plant, bacterium, slime mold, etc. The mammals are the only animals that have hair and feed their young on milk.

The domesticated horse, cow, sheep, and dog are of great value to man. The beaver, fox, bear, and others furnish furs. Skunks, shrews, bats, and armadillos destroy insects.

Courtesy N. Y. Zoological Society

FIG. 47.—AQUATIC MAMMALS—PORPOISES

Mammals that live in the ocean waters are walruses, whales, seals, and porpoises. These are not fish. All of them have hair and suckle their young. The bats are mammals (not birds) which have skin spread between their long toes so they can fly. The kangaroos of Australia and the opossums of America are among the very ancient types of mammals. The highest mammals, and therefore the most highly specialized of all animals, are the gorillas, apes, and man.

Man is, after all, an animal and a mammal in structure and physiology. It is his reasoning brain, upright position, and remarkably clever hands, his ability to talk, and still other things that make him different enough from other creatures.

SUMMARY

The animal kingdom may be classified as follows:

Animal Classification

Phylum 1. **Protozoa.**—With single cells, mostly microscopic; in moist places; may form limestone; germs of some diseases; important for biologic study.

Phylum 2. **Sponges.**—Simple, jelly-like clusters of cells, with harder skeletons. Mostly marine.

Phylum 3. **Polyps and Medusæ.**—Many-celled; bag-like in shape. With alternation of generations. Mostly marine. Jellyfish, sea anemones, corals.

Phylum 4. **Flatworms.**—With ribbon-like bodies; usually parasitic, with alternation of hosts. Liver fluke, tapeworms, etc.

Phylum 5. **Roundworms.**—Bodies cylindrical, without segments. Very abundant, some free-living, some parasitic; of great economic importance. Horse-hair "snake," trichina worm, hookworm, etc.

Phylum 6. **Segmented Worms.**—Bodies more or less cylindrical, with segments and unjointed legs. Earthworms, marine worms, etc.

Phylum 7. **Echinoderms.**—With spiny shells, the body usually with 5 divisions. Wholly marine. Regeneration occurs. Starfish, sea urchins, sea cucumbers, sand dollars, etc.

Phylum 8. **Arthropods.**—Segmented bodies, jointed legs; with considerable chitin in the skin.

Class 1. **Crustacea.**—Two pairs of antennæ, 5 or more pairs of legs. Marine, fresh-water, damp earth. Lobsters, crabs, barnacles, sow-bugs, etc.

Class 2. **Horseshoe Crabs.**—Without antennæ. Ancient group nearing extinction.

Class 3. **Arachnids.**—4 pairs of legs, a cephalothorax, and an abdomen. Land inhabitants; may produce silk. Spiders, mites, ticks, scorpions, daddy-long-legs, etc.

Class 4. **Millipeds.**—Antennæ inconspicuous; with many legs (2 pairs to each segment). Not poisonous.

Class 5. **Centipedes.**—Antennæ conspicuous; with 1 pair of legs to each segment; sometimes poisonous.

Class 6. **Insects.**—With head, thorax, abdomen, and 3 pairs of legs. Growth by molting, the metamorphosis of some forms including larva, pupa, and adult stages; adults do not grow. Economically of great importance as destroyers of food crops and forests, distributors of disease-producing organisms, scavengers, destroyers of other insects, pollinators, etc. Constitute five-sixths of the whole animal kingdom.

Phylum 9. **Molluscs.**—Soft-bodied, usually with external shells. Snails, clams, slugs, octopuses.

Phylum 10. **Vertebrates.**—With bony skeletons.

Class 1. **Fish.**—With fins and moist, scaly skins.

Class 2. **Amphibia.**—With smooth, moist skins; with legs when older; live first in water and then on the land. Frogs, toads, salamanders.

Class 3. **Reptiles.**—With dry, scaly skins; with or without legs. Snakes, lizards, turtles, alligators, etc.

Class 4. **Birds.**—With feathers and wings; of great economic importance.

Class 5. **Mammals.**—With hair; feed their young on milk. Cattle, dogs, cats, horses, whales, seals, apes, man.

DEFINE

The names of the phyla and classes in the animal classification above. Also define:

Marine
Between-tides
Asexually
Sexually
Segment
Host
Gall
Regeneration
Cylindrical
Chitin
Antenna
Antennæ
Cephalothorax
Abdomen
Molt
Metamorphosis
Direct metamorphosis
Indirect metamorphosis
Larva
Pupa
Caterpillar
Maggot
Grub
Vertebra

PROBLEMS

1. How many of the animal phyla are represented by familiar species in your region?

2. How many of the phyla and classes of animals had you ever heard of before you started this biology course? List those you had not previously known. In each case, explain why the group was not known to you before.

3. If you were a fish living in the ocean, which phyla and classes of animals might you meet there?

4. Which of the phyla and classes of animals have ever been represented by live animals inside of your own home?

5. Classify the animals shown in this book in 100 of the pictures which include animals (and which are outside of this chapter). Keep a careful record. What conclusions can you draw as to the abundance, the conspicuousness, and the importance of the various animal groups?

6. Explain why we do not classify the horse-hair snake as a reptile.

7. Which phylum contains the smallest animals? The largest? The most conspicuous? Prove your answer.

8. As far as you know, which phyla contain parasitic species?

9. Which phyla and classes are the most useful, economically, to man?

10. Which three phyla provide the most dangerous enemies of man? Explain your answer.

11. Which phyla and classes of animals have provided food for you?

12. Make a list of the domesticated animals which you know, naming the phylum or class to which each one belongs.

13. Why is it that the vertebrates do not have to molt as the arthropods do in order to grow?

14. Explain the differences in meaning between alternation of generations and alternation of hosts (as the latter occurs in the liver flukes, for instance).

15. Make a list of 25 kinds of mammals that you can identify, giving at least one characteristic that you would depend upon to identify each kind.

16. Do the same for 15 kinds of birds that you can identify.

17. Do the same for 20 kinds of insects that you can identify.

CHAPTER IV

ORGANISMS NEITHER PLANT NOR ANIMAL

In our everyday affairs we commonly think of all living things as plants or as animals. Most textbooks also group all organisms into two great kingdoms; but biologists have realized for many years that there are many simple forms of life which are, strictly speaking, neither plants nor animals. Such things as the slime molds, diatoms, and bacteria do not satisfy our definition of a plant, nor any good definition of a plant. Neither do they fit any definition of an animal.

The bacteria do not have green chlorophyll nor cellulose. They do not manufacture their starch and sugar foods. They have neither leaves, stems, nor roots. Many of the species move about as freely as animals; and yet they resemble plants in their mode of reproduction, including the formation of spores that suggest the spores of fungi.

Primitive Forms of Life

The truth of the matter is that long before there were any plants or animals on this earth, there were living organisms that were neither plants nor animals. They were alive, but they did not possess the other characteristics which present-day plants possess, nor the characteristics which are typical of animals. It was not until the ancestors of the plants and the ancestors of the animals finally developed from this primitive sort of life that there came into existence things which could be called plants or animals.

On the other hand, while some of the simple organisms gave rise to plants and some of them gave rise to animals, there were many other simple forms which remained simple and whose descendants are still simple today. These are the slime molds, bacteria, etc.

If it seems difficult to understand what these things can be that are neither plant nor animal, it is still worth while emphasizing the fact that life existed long before plants or animals, botany or zoology was in existence. The life that is in a plant is really much the same as the life that is in an animal, simply because both are descendants of the same primitive things. Thus it is that in a biology course we may study the living processes which are the same in both plants and animals, and in those organisms that are neither plants nor animals.

It is, however, not fair to say that there are three kingdoms of living things. These simple things represent forms that are as different from each other as the simpler animals are from the simpler plants. The simple organisms represent at least six or eight distinct groups, each of which might be called a separate kingdom but for the fact that only the bacteria have enough species in their group to warrant giving it the title of "kingdom." We shall consider only three of these groups of simple organisms in the present volume.

Slime Molds

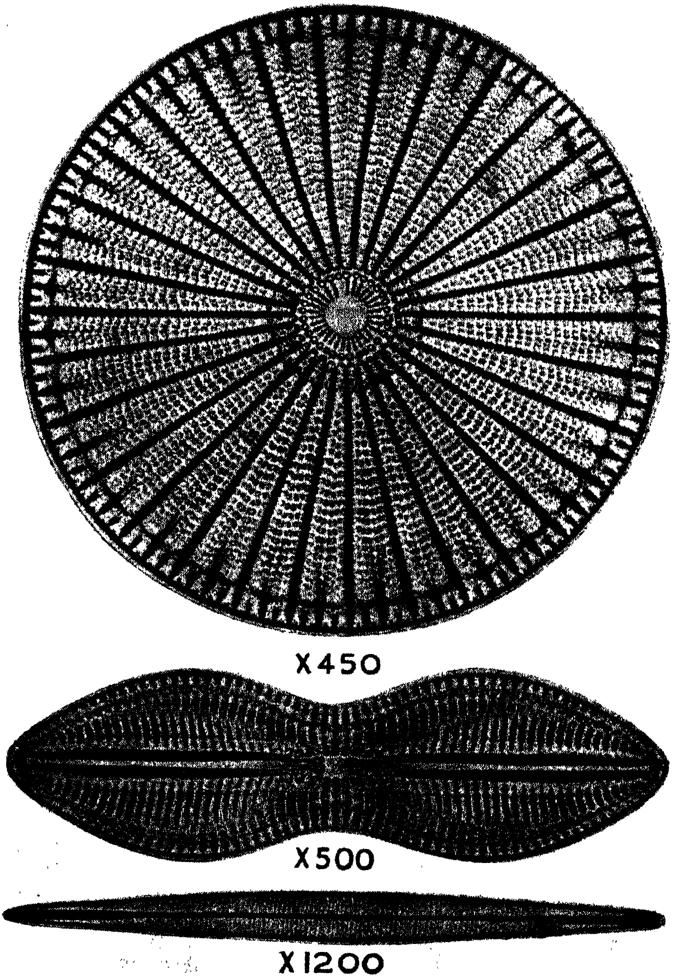
Searching in the late spring or in the summer, on moist, decaying wood, in shaded and in damp corners, one may find a bright-pink structure, a half inch or so in diameter, that looks more like a small, slime-coated puffball than like any other thing with which we are familiar. These, the fruiting portions of a slime mold, will later turn lead gray and, bursting open, will release clouds of dust-like spores. When these spores fall upon a moist surface they absorb water and develop into cells that move about. The movement is brought about by the protrusion of a portion of the cell and the movement of the cell materials into the protruded part. This movement so closely resembles that of the protozoa that slime molds are sometimes included in a zoology course. As a matter of fact, these are among the organisms that are neither plants nor animals.

If moisture is abundant, the cell may develop a thread-like appendage by means of which it will swim about even more rapidly. When the cell multiplies into a mass of cells, the whole mass may still move about as though it were an animal. When the food supply or the moisture becomes scant, the material of the mold gathers together and creeps to a drier location on the outside of the log. Finally there develops the same sort of pink fruiting body with which we began.

Courtesy New York Botanic Garden

FIG. 48.—TWO KINDS OF SLIME MOLDS

There are other slime molds with more complicated life histories. Some of them are responsible for such economically important diseases as clubroot of cabbage and powdery scab of potatoes.



Courtesy Max Poser, Bausch and Lomb Co.

FIG. 49.—BEAUTY IN THE MICROSCOPIC

Three species of diatoms, magnified as indicated on each figure. Actually much too small to be seen with the naked eye. The one-celled, jelly-like organisms live inside these harder, beautifully marked shells. These are front views, showing the tops of the "pill-box covers"; if viewed from the side, the two halves of the box-like shells would be seen.

Diatoms

The diatoms are among the most beautiful of minute things that may be shown up by the microscope. They are abundant in both fresh and salt water. They are called *di* (two) *atoms* (microscopic units) because, although they are usually colorless and single cells, they are made up of two similar portions that fit together like the halves of a pill-box (see the accompanying figures). Sometimes the single cells are united into strings or branching colonies of cells. The diatoms have silica in their cell walls. This material is chemically the same as a chief material in window-glass. The shells of the dead diatoms, tiny as they are, gather in such masses on the bottoms of lakes and of oceans as to build up thick layers of peculiar, earthy substances (called diatomaceous earths) which are of economic importance in silver polishes and tooth pastes. In both fresh and salt waters the diatoms provide considerable food for the smaller crustacea which, in turn, are chief foods of the fish.

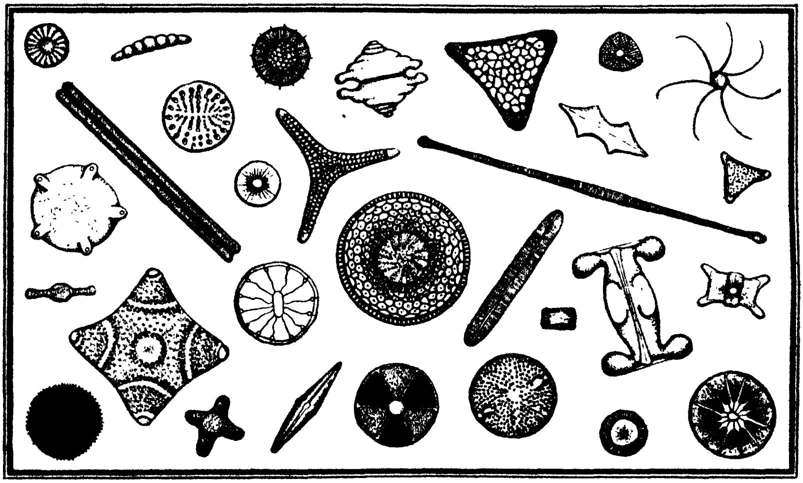


FIG. 50.—THIRTY SPECIES OF DIATOMS

Magnified about 200 times. Each individual is a single cell. The designs represent markings on the glass-like cell walls.

Bacteria

Among the most important of all living organisms are the microscopic creatures which we call bacteria. They were probably among the first living forms on this earth, and they still remain among the very simplest in structure. Bacteria are so abundant and important, and their special study requires such specially-trained workers, that this end of biology is often spoken of as a separate sub-science, *bacteriology*.

Structure of Bacteria.—All bacteria are exceedingly minute organisms that can be seen only with considerable magnification under a microscope.

Each bacterium consists of a single cell which, however, is much simpler in structure than the cells of which plants and animals are made. The bacterial cell does not have its contents separated into the two distinct portions, nucleus and cytoplasm, which appear in all plant and animal cells. (This last statement will be explained in a later chapter.) Often chains or solid colonies of bacteria will form, but each cell remains an independent, individual organism. Many bacteria are able to move about as a result of the whipping action of thread-like processes attached to the bodies of the cells. Some bacteria may travel at a speed which, in relation to their size, is as great as that of a running man.

Bacteria multiply by the very simple process of having their cells divide into two. Under favorable circumstances the cell division may occur as often as every half hour. This accounts for the tremendous abundance of bacteria and the great importance of these microscopic creatures. If conditions were ideal the descendants of a single bacterium might number hundreds of billions of individuals by the end of two days. If bacteria get into unfavorable conditions they may live for years without multiplying. They have been obtained from soil which has been kept dry for over fifty years in sealed fruit jars.

Occurrence of Bacteria.—Because of their small size the bacteria were not discovered until two centuries after

Columbus had discovered America. In 1683 a Dutch merchant, Leeuwenhoek by name, using newly improved microscopes of his own design, first made the observation which so many boys and girls now make each year in elementary labora-

From a painting, courtesy Bausch & Lomb Optical Co.

FIG. 51.—ANTON VAN LEEUWENHOEK, DISCOVERER OF BACTERIA, 1632-1723

Note the simple microscope which he is holding, and the common household materials through which he is searching for the curious things that can be revealed by his instrument.

tories. He scraped some tartar from his teeth, and mixing it with water, placed it under a microscope. He wrote: "I . . . . then to my great surprize perceived that the aforesaid matter contained very many small living Animals, which moved themselves very extravagantly. The biggest sort had . . . . their motion . . . . strong and nimble, and they darted themselves thro the water or spittle, as a Jack or Pike does thro the water. . . . . The 2d. sort . . . . spun about like a top. . . . . In the 3d. sort I could not well distinguish the Figure. . . . . These were so small . . . . and . . . . so swift, that I can compare them to nothing better than a swarm of Flies or Gnats, flying and turning among one another in a small space. . . . . Besides these Animals there were a great quantity of streaks or threds of different lengths, but like thickness, lying confusedly together, some bent, and some streight . . . ."

Later observers added to our knowledge of these microscopic organisms, but it was nearly two hundred years later when the work of the French chemist and biologist, Louis Pasteur, first showed the widespread abundance of bacteria and explained their great importance.

There is hardly a corner of this world in which bacteria are not to be found. There are species that are active in temperatures very near that of freezing water (32° F.), and most species can live in an inactive condition for long periods at temperatures far below freezing. Others persist in the hot springs of our West at temperatures of nearly 200° F. Most bacteria, however, thrive best at about 100° F., which explains why the decay and disease for which they are responsible become widespread during summer weather.

Many bacteria are killed by direct sunlight. Many bacteria need oxygen for their best growth, but there are species that live in the deep soil at depths as great as 3,000 feet, in places that are absolutely free of oxygen. Most bacteria thrive best in moist or wet locations, but they may form inactive spores which will live for many years under very dry conditions. Bacteria are killed by certain poisons, however, including strong brine (such as is used in pickling meats and in making salted meats), formaldehyde (often called formalin), corrosive sublimate, carbolic acid, lysol, 70 per cent alcohol, calcium hydroxide (quick-lime), bleaching powder (if fresh), and others. Many of these things are poisons that are deadly to man and should be handled only by an experienced person. Many commonly used materials, like burning sulphur candles, are not reliable germ-destroyers.

From the above it will be seen why bacteria thrive in many places where no other organisms could exist, and in all plant and animal materials which have not been absolutely sealed against their entrance.

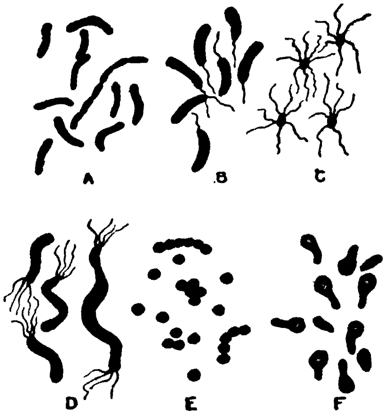


FIG. 52.—BACTERIA, MUCH MAGNIFIED

A, tuberculosis; B, cholera; C, typhoid; D, decay; E, pus; F, lockjaw.

Importance of Bacteria.—There are more than a thousand described species of bacteria, and they affect man and other organisms in many different ways.

Some of the bacteria are capable of taking nitrogen gas out of the air, and of using it in the manufacture of certain kinds of foods which we call proteins. Milk and meats contain considerable proteins, and we shall later learn what important aids the bacteria are in the making of such protein foods.

Other kinds of bacteria, along with the yeasts which we have already studied, are responsible for the fermentation that produces alcohol; and for the fermentation by which cocoa and chocolate are prepared from the cocoa-bean. Bacteria are responsible for many of the changes by which raw leather is turned into tanned leather which may be used in making shoes and other goods. Bacteria aid in turning cider into vinegar, in the souring of milk, and in the production of cheese and other milk products.

Still other bacteria cause the decay by which dead stuff is removed from the surface of the earth. We are all familiar enough with decay as it occurs in fruits and vegetables, dead animals, and other dead things; but we should realize that bacteria are the things that cause this breakdown and decay. Without decay bacteria, accumulations of dead stuffs would soon pile so deep as to make the world uninhabitable.

N. L. Cary photo. Courtesy U. S. Forest Service

FIG. 53.—IF THERE WERE NO BACTERIA OF DECAY—
Accumulations of dead stuffs would soon make the world uninhabitable.

While the above bacteria are beneficial in their relations to man, and while most of the species of bacteria are of no importance at all, there are some kinds which are responsible for diseases that occur in man and his domesticated plants and animals. These disease-producing forms are commonly called "germs," just as other microscopic organisms (protozoa, round-

DEFINE

Slime mold
Diatom
Silica
Diatomaceous earth
Bacterium
Bacteriology
Leeuwenhoek
Pasteur
Decay
Germ
Bacteria

PROBLEMS

1. Find a specimen of an organism which is neither plant nor animal and take it to class. Or find things which show that the organisms are or have been present, even if they are not visible to the naked eye.

2. Make a chart showing the number of individuals in each generation, starting with one bacterium that divides into two, doubling the number of individuals in the colony once each hour for two days.

3. What means are employed to prevent bacteria from entering human foods?

4. What methods are employed in your home for preventing the *rapid multiplication* of bacteria in foods?

5. What processes are used to kill bacteria that may already be in human foods? Give a definite case of the use of each method.

6. In how many forms could such a meat as beef be preserved so it would remain fit food and not decay? In which form would it be preserved the longest?

7. Make a list of 25 foods that could be carried on an exploring expedition without danger of decay, even though no method of refrigeration were available on the trip.

8. What explanation can you give for the fact that children contract contagious diseases more often than adults?

9. Farmers often store corn-stalks for winter feeding of cattle by cutting them into small pieces and packing them tightly in a tank-like structure called a silo. Why is it that the food does not spoil in a silo?

10. Make a list of the ways in which organisms that are neither plant nor animal have affected your own life.

11. Gardeners accumulate all of their plant cuttings in a *humus pile* which, after it has decayed, is a source of rich fertilizer. Why is it good practise to keep such a pile dug so that its contents are constantly being turned over?

CHAPTER V

NAMING AND CLASSIFYING ORGANISMS

Now we shall learn some things about the way in which organisms are named and classified.

Naming

We have already said that every plant and animal must have a name. It is true of your human acquaintances.

FIG. 54.—GETTING ACQUAINTED

Indeed, everything that you know must have a name. If you don't have a name for it, you don't know it. Perhaps the name you use is not a convenient one, nor the one that others are using, but nevertheless it is the name, the handle by which you always take hold of the thing when you start to talk or think about it.

Perhaps you know some person, for instance, as "that-dark-young-man - that - goes - rapidly - by - my - house - just - before - my - breakfast-each-morning." You have probably never said that name aloud, but you think it, or a part of it, more or less unconsciously, every time you think at all about the man. That, of course, is not the name that he applies to himself, but it is the only name you know for him, and you have to use it until you learn a better one.

The young man's correct name may be Horatio Hittlesby. That is not a pretty name, but if you once learned it you could forever after use it or some nickname. Even Horatio's correct name is more convenient than your thought-name for him. And—what is more important—it is the name which other people use for him, and they will know whom you mean when you use that name.

Rules for Naming Organisms.—Similarly we should have convenient and correct names for plants and animals. Then they may be understood by scientists all over the world. In order to accomplish this, biologists have agreed on a set of "International Rules" for naming organisms. Whenever you see scientific names, remember they are the best things that such rules can produce.

The rules state that all organisms should have Latin (or Latinized) names. One reason for this is the fact that practically everything written a hundred and fifty years ago, when scientific classifications were first made, was in Latin. Another good reason is that Latin is a dead language, and no living scientist can feel insulted because his own language is not used. This is really not such a small matter, as you will agree when you think of the bitter jealousies that still exist between some of the nations that have been at war during this century.

Latin Names.—Of course, we ourselves often use English names for things, but they are not always satisfactory. In many cases they are not understandable beyond the limited region in which we may live. Thus the trailing arbutus of New Jersey is known as a mayflower in New England, although it is the azalia of New England that is called a mayflower in New Jersey. Similarly confusing is the name gopher, for it is applied to a turtle in the South, to a rat-like animal in California, to a snake in Idaho, and to a ground-squirrel in Montana. Such difficulties with English names could be illustrated many times. You will see why there have to be standardized scientific names for use in literature that will have an international distribution.

English names are used in most places in this book because they may prove less strange than the Latin names, but if you ever study more botany or zoology you should expect to learn the scientific names of things. They are really not so hard to pronounce or to remember. You are already using some of the worst, like rhododendron and eucalyptus and hippopotamus. Most of them are as easy as English names: *Bombus* is the Latin for the bumblebee, *Acer* for the maple, *Quercus* for the oak, *Salix* for the willow. Many scientific names are much like the English names in spelling and pronunciation: *Rosa* is the name for the roses, *Viola* for the violets, *Orchis* for one of the orchids, *Iris* for the iris (or flag lilies), *Aster* for the asters, etc. Nursery catalogs and many popular books are beginning to use Latin names, and you ought to learn them as you have the opportunity.

Courtesy N. Y. Bot. Garden

FIG. 55.—LINNÆUS IN LAPLAND DRESS
At the age of thirty.

Generic and Specific Names.—All scientific names have two or three parts. For the very same reasons, your name has not less than two and probably not more than three parts.

Single names are, of course, impossible, for there aren't enough of them to go around. If Horatio didn't have any other name you might not know which of several Horatios was meant. But when his ancestral name, Hittlesby, is also used, the difficulties are reduced.

Biologists formerly gave organisms very much longer names, which were really brief descriptions. For instance, one of the common, large wasps was called *Vespa thorace nigro, antice rufo immaculato, abdominis incisuris puncto nigro duplici continguo*, meaning "a wasp with a black thorax which is red in front, and with an abdomen marked with double, black spots which touch each other." That was something like the thought-name you first gave Horatio Hittlesby. Strange as it may seem, no better way of naming things was discovered until about 1750, when Carolus Linnæus, a native of Sweden, developed the system of shorter names which we now use. You may see what an improvement his system was by comparing the above with the present name of the hornet, *Vespa crabro*. Without this simpler system, biology would find it very difficult or impossible to talk about the things it studies. We owe a great deal to the work of Linnæus.

In Latin, if you will remember, the important word comes first, so when Linnæus re-named the hornet he put the *Vespa* (meaning wasp) first, for it is the ancestral or, as we say in biology, the *generic* name of the insect; and *crabro* (meaning hornet) second because it is the name of only the particular kind or *species* of *Vespa*. The first part of every scientific name shows the genus and the second the species of the organism. If a third name is given, it indicates the variety.

Names of genera always begin with capital letters; other names usually begin with small letters. All of this is illustrated by the following:

Acer saccharum is any individual tree of sugar maple.
Acer saccharinum is any silver maple.
Acer rubrum is any red maple.
Acer rubrum tridens is a small-leaved variety of red maple.
Acer rubrum drummondii is a downy-leaved variety of red maple.

Rule of Priority.—If, through some accident, two different scientific names are given to the same organism, the rule of priority states that the first properly published name is the correct one. Thus the live oak of the southeastern United States, which was named *Quercus virginiana* in 1768 and *Quercus virens* by another scientist in 1789, has *Quercus virginiana* for its correct name.

For various reasons changes have to be made sometimes in scientific names, but there is, on the whole, considerable agreement as to the names we should use.

When a biologist finds a plant or animal which seems to him to be different from anything yet named, he calls it a "new species" and gives it a Latin name. The species may be as old as the hills—a million years old—but it is new in the sense that no taxonomist has previously described it. The scientific discoverer then proceeds to publish the new name, usually in some monthly, scientific journal, along with such a description as will help other people to know the species when they come across it and to use the same name for it.

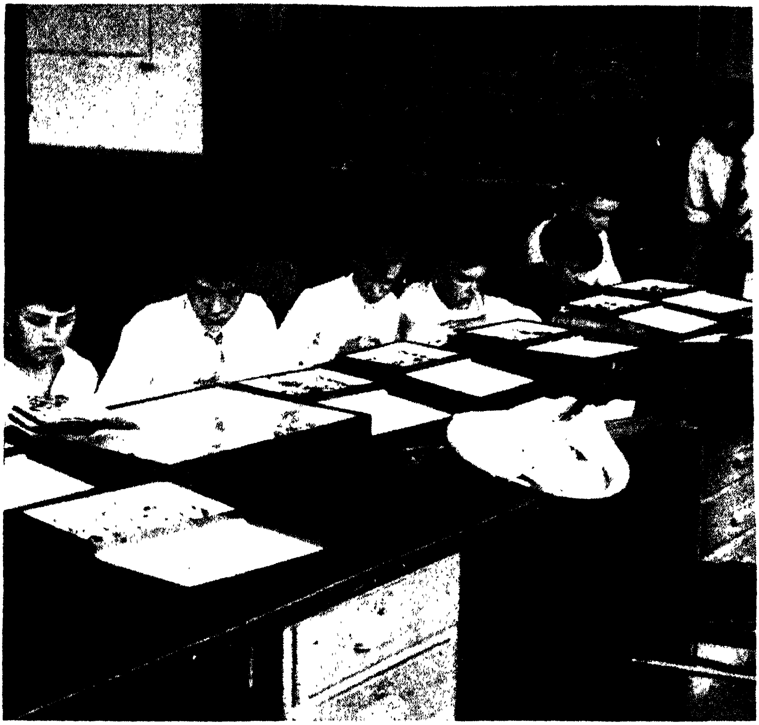
Classifying

As we have already pointed out, there are perhaps two or three million species of plants in this world, and as many animals. It would never be possible to keep track of so many names or to keep in order our knowledge of so many organisms if we didn't classify them in some way.

Scientific classifications arrange species in main groups and in sub-groups, somewhat like the arrangement of the names in a telephone directory, the cards in a library catalog, or the stamps in a well-ordered album. In the telephone directory all of the names are put into twenty-six main groups named for the letters of the alphabet, and under each letter subdivisions are again made. All the *Ab's* are put together, the *Ac's* in another group, and so on. Each sub-group has still further subdivisions, as you know. Without such an arrangement the directory would not be usable.

Each plant or animal that we may observe is an individual organism. No two individuals are exactly alike, yet it is possible to see many resemblances between some of them, and such similar individuals may be placed in one group in our classification. For instance, although no two individual squirrels are exactly alike, we can include many of them under the single name of gray squirrel. We refer to such a group of similar individuals when we speak of a *kind* or a *species* of plant or animal.

But it is clear that there are other species of squirrels, the red squirrel, the fox squirrel, the pine squirrel, and others,



Courtesy Prof. J. J. Davis, Purdue Univ.

FIG. 56.—CLASSIFYING THE DAY'S CATCH

Insects are so abundant that bug-hunting provides endless opportunities for real explorers. But a classified collection is much more interesting than disorderly boxes of material. Can you explain why?

and it is just as clear that all of these species might be grouped together. Such a group of similar species is a *genus*. These squirrels belong to one genus. The various kinds of chipmunks belong to another genus. The prairie dogs are in a still different genus. Similarly, among the plants, all of the oaks belong to one genus, the maples to another, and the willows to a third genus.

In the same way, similar genera belong to a family, similar families to an order, similar orders to a class, and similar classes to a phylum. All of this will be clearer from the following arrangement, where the larger groups are placed first, and where the classification of one of the varieties of the gray squirrel is given as an example.

- **Phylum.** *Vertebrata.* Vertebrates (including all animals with bony skeletons).
  - **Class.** *Mammalia.* Mammals (including all hairy vertebrates).
    - **Order.** *Rodentia.* Rodents (gnawing mammals, like rats, rabbits, squirrels, etc.).
      - **Family.** *Sciuridæ.* Squirrels and their relatives.
        - **Genus.** *Sciurus.* True squirrels.
          - **Species.** *Sciurus carolinensis.* Gray squirrel.
            - **Variety.** *S. carolinensis leucotis.* Northern gray squirrel.
              - **Individual.** Any particular squirrel of this variety.

You will see that we did not get very far in our plant and animal classifications when we considered only their phyla and classes.

To show you what biologic classifications look like, here are the families of our American rodents. The genera are given for only one of the families, and the species for only one of the many genera. Examine some book that gives a more complete classification of some group of plants or animals.

AMERICAN RODENTS

- Order. *Rodentia.* Rodents.
  - Family 1. *Sciuridæ.* Squirrels.
    - Genus 1. *Marmota.* Woodchucks.
    - Genus 2. *Otospermophilus.* Rock squirrels.
    - Genus 3. *Callospermophilus.* Ground-squirrels.
    - Genus 4. *Citellus.* Ground-squirrels.
    - Genus 5. *Ammospermophilus.* Antelope ground-squirrels.
    - Genus 6. *Cynomys.* Prairie-dog.
    - Genus 7. *Eutamias.* Western chipmunk.
    - Genus 8. *Tamias.* Eastern chipmunk.

Genus 9. *Sciurus.* Tree squirrels.
  Species. *Sciurus hudsonicus.* Red squirrel.
    S. douglasii. Pine squirrel.
    S. fremonti. Chickaree.
    S. carolinensis. Eastern gray squirrel.
    S. griseus. Western gray squirrel.
    S. aberti. Tuft-eared squirrel.
    S. niger. Fox squirrel.
    S. apache. Apache squirrel.
    S. arizonensis. Arizona gray squirrel.
Genus 10. *Glaucomys.* Flying squirrel.
Family 2. *Geomyidæ.* Pocket gophers.
Family 3. *Heteromyidæ.* Kangaroo rats and pocket mice.
Family 4. *Castoridæ.* Beavers.
Family 5. *Cricetidæ.* Rats, mice, muskrats.
Family 6. *Muridæ.* Old World rats and mice.
Family 7. *Aplodontiidæ.* Mountain beavers.
Family 8. *Zapodidæ.* Jumping mice.
Family 9. *Erethizontidæ.* American porcupines.

You should observe certain little matters which are the marks of an educated person. Remember that both the singular and plural forms of the word *species* are spelled and pronounced alike, that the plural of *genus* is *genera,* and that the plural of *phylum* is *phyla.* And be careful never to speak of a "variety" or a "family" or a "class" of plants or animals, or to use any other such group name unless you intend exactly what the name stands for among biologists. These are small details, but they make it easier to talk accurately about plants and animals.

Showing Relationships

In addition to naming and classifying organisms, in which occupations biologists have always engaged, modern taxonomy tries to arrange species so as to show their real, ancestral, or "blood" relationships. This is possible because we now believe that species or other groups that show similarities have really had, in some remote age, the same common ancestor;

although the two species have become different as they have come down their separate lines of ancestry.

Thus we group gray squirrels, red squirrels, fox squirrels, and others in the one genus *Sciurus*, not only to obtain a convenient classification, but also to show that we believe that all the species in that genus have had a common ancestor in the remote past. This principle applies not only to genera, but to all other taxonomic groups as well.

It is not always easy to tell whether two groups of organisms are really related. No man was on hand, millions of years ago, to make historic records of their origins.

Surface resemblances are not safe guides to relationships. Consequently there are mistakes enough in the best of our classifications, but they do give some information about the ancestral histories of organisms. Remember this whenever you meet with scientific classifications of plants or animals.

SUMMARY

1. It is the business of taxonomy to name and classify organisms and to show their ancestral relationships.

2. Everything must have a name or it cannot be talked about or even thought about.

3. In order to have names that are convenient and standardized throughout the world, biologists have adopted International Rules for naming organisms.

4. Scientific names are Latin in form. English names are not well standardized and could not be used internationally.

5. The first part of a scientific name shows the genus to which the organism belongs; the second part is the name of the species; a third part may be the name of the variety.

6. The Rule of Priority states that the first properly published name is the correct name. The first scientist who publishes a description and gives a correct scientific name to a plant or animal is referred to as the discoverer of that species.

7. Scientific classifications are catalog arrangements useful for keeping our knowledge about the many plants and animals in order.

8. The groupings in such classifications are called phyla, classes, orders, families, genera, species, and varieties. These groups are arranged in precisely this order.

9. Scientific classifications are also intended to show the ancestral or "blood" relations of the species in the classification, as far as it is possible for scientists to secure information on the ancestral histories of organisms.

DEFINE

International Rules
Scientific name
A "new species"
Classification
Phylum
Class
Order
Family
Genus
Species
Variety
Individual

PROBLEMS

1. Make a list of other plants or animals for each of which you happen to know more than one English name.

2. Why do we feel that biologic classifications are more *real* than the classifications of card catalogs, directories, etc.? It is not merely because we classify *living* things in biology.

3. Is it more interesting to learn the names of species or to learn the names of phyla and classes? Why?

4. Why did we study the names of the phyla of plants and of animals instead of the species of the plants and animals?

5. In some encyclopædia or history of biology find something more about the life of Linnæus, and prepare to make a report to the class.

6. Make a list of the cultivated plants whose Latin names you happen to know. In many cases, the most commonly used names for such plants are really the Latin names.

7. The classifications of plants, animals, names in the telephone directory, and books in a library are mentioned in this chapter. What other things have you ever seen classified according to some well-worked-out system of classification?

8. If one collected a large number of leaves of trees, would it be possible to classify them without knowing their names? Be careful of your answer!

CHAPTER VI

TAXONOMISTS AS EXPLORERS

By this time you may want to know why some men spend their whole lives giving names to plants and animals, and arranging them in classifications.

The answer is that scientific research is done chiefly because scientists like to do it—for the fun of it! You may not think that a very worthy thing to admit, but isn't that the best reason for most of our occupations? If the work itself doesn't bring the pleasure, at least the results do. The finding of happiness and making others happy are worth-while things in life. This world needs a great deal of happiness.

Let me show you what fun taxonomists have in naming and classifying things!

Collecting

To begin with, somebody has to collect the specimens that a taxonomist is to study.

Most of us like to collect things, and some of us have quite a dose of that instinct. Some folks collect stamps, others collect cigar-bands, or autographs, a pocketful of junk, or dollars and dollars. Whatever their value or lack of money value, all collections are very real possessions to their owners. If your collection is larger, even a shade larger, than any other like it in the world, that greatly increases your happiness. It shows how thoroughly you have completed your work, in what good order you can arrange the specimens, with what surpassing wisdom you can exhibit them, with what authority you can speak on your subject. Taxonomists aren't so different from the rest of you who do a bit of collecting.

Only, of course, they feel sure that plants and animals are the finest of all things to collect. They are live things to begin with, and there are endlessly interesting facts to be noted about them. The collection is the permanent record of the out-of-doors.

Don't go collecting unless you are going to make observations of the live creatures. Keep a record with each specimen in your collection to show such things as when and where it was gathered and the sort of country in which it lived, and perhaps what food it ate, how it moved, where it laid its eggs, and other such intimate things. Often it is well to keep the specimen alive and growing where you can watch it day after day until you have learned a great deal about its ways.

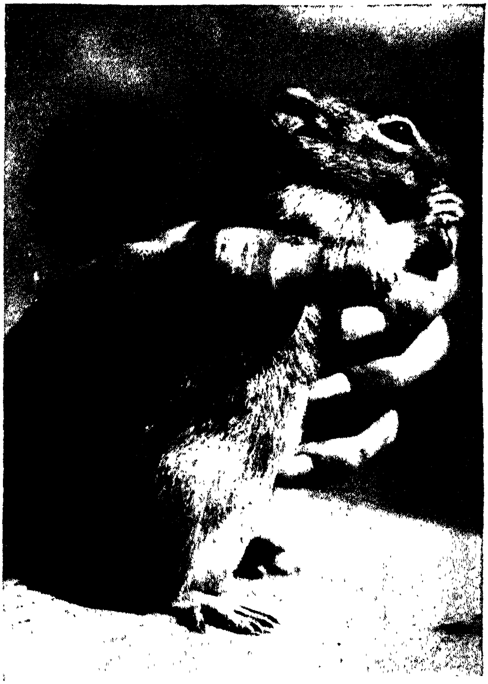


Photo by D. Johnson. Courtesy U. S. Forest Service

FIG. 57.—THE PHOTOGRAPHIC RECORD

Striped chipmunk, Oregon.

What to Collect.—Some organisms are pitiful specimens in a collection, but many are very beautiful. Butterflies and moths, properly displayed, might find ready places as decoration in the finest of homes. Most insects look well and are easily kept. Shells make very interesting collections. The plant materials that preserve nicely are woody fungi, tree sections, seeds, and coarser leaves. Flowers, ferns, soft fungi, and softer animals that are not easily preserved should be drawn or photographed. If you use a camera, you will find the photography of living things, especially of active animals, a feat to thrill you. And a garden of living wild flowers makes a very fine sort of collection.

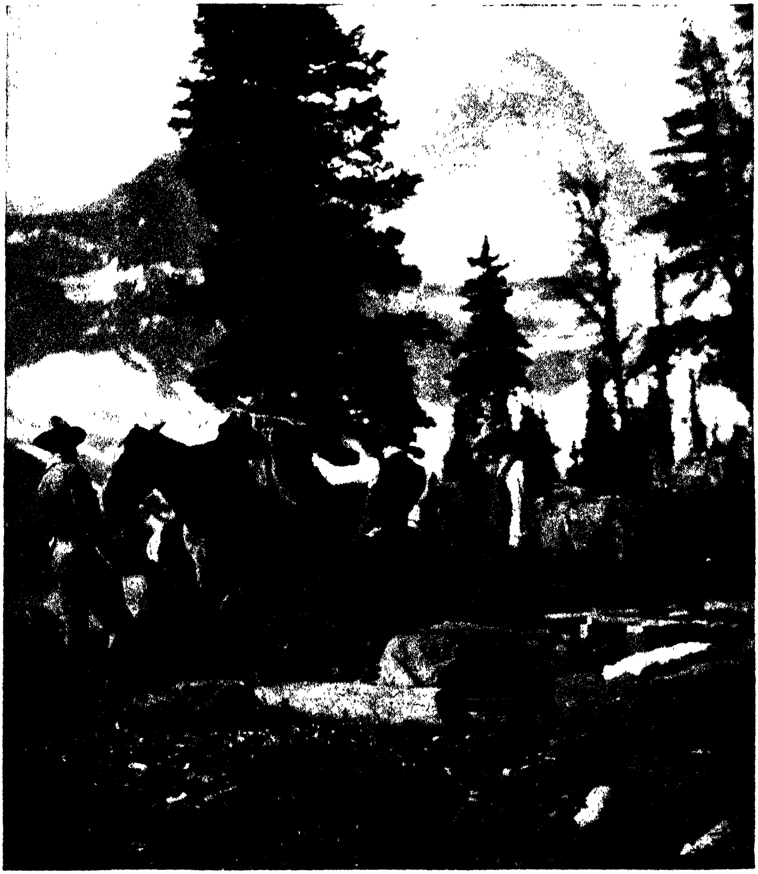
Conservation.—Protect rare things in your collecting. Remember the old rule: Of a little, take a little, and leave a little. Birds, most mammals, and some rare flowers are altogether too valuable to be killed at all, except for the collections of the larger scientific institutions; but you may gather records of those species showing where and when and under what circumstances you observed them.

You see, I want to make collectors of some of you. I think that you too may find it a pleasurable occupation—if you don't forget you are collecting living things.

Making Discoveries

If, in making a collection, you should discover an undescribed and wholly new insect or plant or other such thing, then you might properly become as excited as Columbus finding a new continent, or Balboa discovering the Pacific Ocean. To the discoverer the importance of the find is not in its money or political value, but in the simple fact that it is a brand-new thing.

The new continents and new oceans are, mostly, all discovered; but biologists still find plants and animals furnishing the pleasures of real exploration. This sometimes involves travelling to the ends of the world. There is no country, no wild and rugged region, that has not been invaded by the taxonomists. In my own small list of friends is one who recently collected in Central America, another who spent last spring in the Guianas, several who have travelled to Australia, two who have crossed and recrossed the wilds of the African jungles, another who went into China, one who knows Newfoundland and Labrador, one who, with his students, has crossed and gone the length of South America, and over mountains and down rivers in regions hardly heard of by the



Courtesy C. D. Walcott and Smithsonian Inst.

FIG. 58.—EXPLORING IN THE CANADIAN ROCKIES
U. S. National Museum party breaking camp.

civilized world, and many others who have gone into the still wildest parts of our own country. All of them were hunting plants or insects or fish or reptiles or some such thing.

Exploring at Home.—Within the bounds of our own country there are great areas that still repay exploration. Many a swamp, forest, and mountain region has been seen by few white men, except, perhaps, by lumbermen, mining prospectors, and scientists. There, geologists have gone to study land formations, paleontologists to hunt fossils, rangers to guard the forests, and taxonomists to make their collections. Northern and eastern Maine, the northern Adirondacks of New York, the southern mountains from Virginia into Georgia, the deserts and western mountains of Texas, the enchanted lands of New Mexico and Arizona, and the tremendous mountain stretches from the Rockies to the Pacific are hardly yet touched biologically.

Photo by Herbert Lang. Courtesy Amer. Mus. Nat. Hist.

FIG. 59.—COLLECTIONS MADE IN AFRICA
Starting on their journey to the American Museum of Natural History.

For that matter, except with birds and trees and other conspicuous things, new plants or animals may be easily discovered almost anywhere in the United States, if one knows enough about the group to recognize new species when he sees them. In a certain family of fairly conspicuous insects one biologist recently collected about 200 species near Austin, the state capital of Texas, and less than 20 of these had ever before been named. It is probable that not a quarter of the Indiana species of that family are yet known to science. One may go exploring, if he will, even close to home.

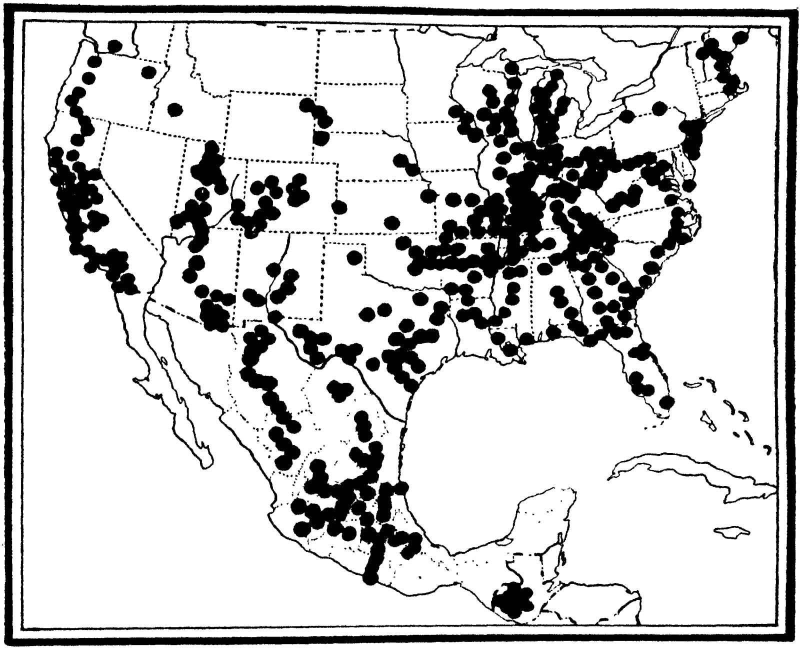


FIG. 60.—75,000 MILES BUG-HUNTING
Each dot represents a locality at which the author has done field-work in connection with research studies on a single family of insects, the gall wasps.

Serving Biology

Not only taxonomists, but all other biologists must know the correct names for the organisms they are studying. The other biologists must go to the taxonomist to get these names.

For instance, the insect that is attacking our crops must be "determined" (its correct name given) by the taxonomist, and he can tell whether it is a native or imported pest, what dangerous habits it or its relatives possess, and perhaps where it is born, how long it lives, and what else it does in its life. Many of the things we do to control the pest will be based on the taxonomist's report.

Fruit Fly in Florida.—Thus it was that when larvæ of a new sort of fly were discovered by inspectors among the orange and grapefruit orchards at Orlando, Florida, on the sixth of April, 1929, they were immediately hustled off to Washington where taxonomists set to work to examine them. On April ninth the taxonomist pronounced the insects Mediterranean fruit flies, and immediately all of the scientific forces of the state and nation were mobilizing for the fight on what was known to be one of the most destructive pests of fruits and vegetables that the tropics could have sent into our country. By the tenth, thirty-five trained men were in the field, trying to discover the extent of the infestation. Within another week the state of Florida had provided the first funds for the fight, and called out the National Guard to enforce the necessary quarantines. By the second of May the federal congress had appropriated four and a quarter million dollars for the work, and the state of Florida was at war—at war with an enemy that might have made the state bankrupt, but a war that was to result within a short year in the extermination of the pest—a war successful in part because of the promptly available knowledge of the taxonomists who were the fly specialists at Washington.

It is much as with a physician. Unless he diagnoses the disease he cannot properly treat it. But if he correctly determines its name he may find out what other physicians know about the same disease, and how they treat it. The taxonomist is the one who diagnoses cases (species) for the rest of biology. In this service comes one of the pleasures of taxonomic work.

Studies on Species.—Within recent years taxonomists have been making intensive studies of the distribution and the characters of species in order to learn how new species come into existence. This is one of the most important problems in the whole of biologic science, and some of the things which we shall learn in later chapters of this book about the origin of new species will be the results of the investigations of taxonomists.

FIG. 61.—EXPLORING AT HOME
Within sight of the country's largest city, the winter out-of-doors provides opportunity for interesting discoveries.

Living Out-of-Doors

Finally, many of us are taxonomists because the work takes us into the out-of-doors.

Were I a king to call for things, every time I would summon my wool shirt and my khaki trousers, and together we would hike some trail. In the evening we would sit before a fire, and I would tell you about some of my collecting days. I would tell you of forests and of rivers, of mountains and of deserts, of winters and of summers, of the trails and of the camps.

FIG. 62.—CAMP IN A CACTUS DESERT

FIG. 63.—GIANT AGAVE, RELATIVE OF THE CENTURY PLANT

FIG. 64.—NATIVES INTERESTED IN OUR CAMP

FIG. 65.—DIGGING OUT OF A SAND BANK

FIG. 66.—SEEN ALONG THE HIGHWAY

FIG. 67.—THE NATIVE TOWN

FIG. 68.—OAK FOREST IN MOUNTAIN COUNTRY

FIG. 69.—THE DAY'S COLLECTION: INSECTS AND PLANTS

TAXONOMIC EXPLORATION IN MEXICO

Such things are not often written into biology books, but they are part and parcel of a biologist's life, and you should know about them.

There was our camp in the Maine woods, where the snow lay deep, and the thermometer dropped below zero; where the expanding ice on the lakes boomed like cannon, where the beaver threw scores of trees on the windy night, and the deer and the bear came close to gaze curiously into our campfire. Yes, there was that camp—but my mind wanders to others. ——I recall one day in the Great Smoky Mountains of the Carolina: Where we started at four-thirty in the morning, climbed upward trails through the day, won our peaks, drank long and deeply of mountain views, hardly got down the trail by sundown, hiked miles in the moonlight, passed the Indian village dancing its old dances, and rode on the log train after midnight. And—there were the New Mexican deserts; and there one night a goat rancher and a forest ranger waited

Courtesy U. S. Geological Survey

FIG. 70.—MEMORIES OF THE TRAIL

for me to come out of the mountains; but I had lost my trail in the dark and had to drop into the canyon and climb down for weary miles, over the boulders and through the water, hitting cactus thorns that made my hands fester for a month; and the two waiting men used profanity; but I had found some very fine specimens in those mountains!

I have put up with lumberjacks and miners; slept with hermit prospectors whose blankets were indescribable and unforgettable; met cattlemen and sheep herders, and folks of many other sorts, even including a few outlaws; have been held for a day by moonshiners; have passed bulls in narrow canyons; have crossed cattle- and wolf-spotted deserts; and once lived for four days in the mountains of southern Arizona without seeing another human being. Sixty thousand miles we have seen of the far ends of our own country. We have worked another fifteen thousand miles of nearly impassible backroads and made some hundreds of camps in the mountains of Old Mexico and Central America. For some future year we plan bug-hunting in the Balkans, and in Asia Minor. Of these days that have gone and days that are to come I might tell you, rambling along, if our fire burned not too low.

In all of these days I have collected insects. I have also collected memories of trails, of hundreds of camps, of such folks as are to be met, and of stretches of glorious countries. I am not certain which of my collections is the more precious.

But now do you see why some men are taxonomists?

SUMMARY

1. Scientific research brings the happiness that is to be obtained through any kind of exploration.

2. The spirit of the stamp collector or collector of anything else is one of the things that inspires the taxonomist; but biologists believe that plants and animals, especially if they are studied while alive, make the best of all things to collect.

3. The thrill of the discoverer of oceans and continents may be had by the biologic explorer. We have hardly begun the exploration of the

world of plants and animals, even of those that are to be found in our own part of this country.

4. It is only after taxonomists have determined the names of their material that other biologists can learn what is known about the organisms in which they are interested. Insect or plant pests may be controlled only after their names are determined.

5. In their contact with live plants and animals out-of-doors, taxonomists are learning much about the origin of new species.

6. Finally, it is the out-of-door life of the taxonomist that has led many men into this part of biology.

DEFINE

Taxonomist	Research
Explorer	Taxonomic determination

PROBLEMS

1. What collections have you ever made, of stamps, autographs, minerals, plants, or other things? Why was it worth while? Prepare to report to the class.

2. Do you think that you have ever seen an insect or other organism that was unknown to science? Explain your answer.

3. Why do most people fail to discover new plants and animals, even though undescribed species are so abundant?

4. What was the most interesting collecting, hiking, camping, or other out-of-door experience that you have ever had?

5. Read at least one of the reference books on taxonomic exploration, noted in the bibliography on page 105. Report briefly to the class; or report on some account of scientific exploration which you have already read.

6. Make a list of English names of plants or animals which, for one reason or another, seem to be poor names. For example, dog-tooth violet is not a violet; sour grass is a name applied to two unrelated species of plants; etc. Be ready to explain the objection to each.

7. From newspaper or magazine accounts, or from the official publications of universities or museums, make a list of places being explored and objectives of biologic expeditions that are now at work somewhere, or that have been in the field during the past year.

8. Name some practical dollars-and-cents values in the work of taxonomists who explore in strange and unknown lands.

TAXONOMY: REVIEW

1. Be prepared to define each of the words listed at the ends of Chapters I through VI.

2. Study all of the summaries at the ends of Chapters I through VI. Make sure you understand and can explain the meaning of each statement made in those summaries.

3. Review the problems given at the ends of Chapters I through VI.

4. The most important principles in Part I of our Biology course—the things you ought to remember and understand twenty years from now as well as in the present review of your work—may be listed as follows:

CHAPTER I. **Life.**—Biology is the science which deals with all living organisms.

The qualities of life are remarkable and not easily understood.

CHAPTER II. **Plant Groups.**—Taxonomy is the biologic science in which organisms are named and classified, their ancestral relationships shown, and their distribution studied.

We should know where, in the accepted schemes of classification, to put each of the plants and animals with which we are familiar.

The main groups of plants are the algæ, fungi, mosses and liverworts, fern and fern allies, and seed plants.

CHAPTER III. **Animal Groups.**—There are 10 main groups of animals, of which the most widely distributed are the protozoa, roundworms, segmented worms, arthropods, molluscs, and vertebrates.

CHAPTER IV. **Organisms Neither Plant Nor Animal.**—There are living organisms which are neither plant nor animal. Among these are the slime molds and diatoms, and the widespread and exceedingly important bacteria.

Bacteria are important in the manufacture of nitrogen foods (proteins), fermentation, decay, and plant and animal disease.

CHAPTER V. **Naming and Classifying Organisms.**—There are International Rules for naming plants and animals.

For convenience we group (classify) organisms as varieties, species, genera, families, etc.

In the scientific classification we also attempt to show the true, ancestral relationships of the species.

CHAPTER VI. **Taxonomists as Explorers.**—The pleasures that reward the explorer may be had in the discovery and study of species.

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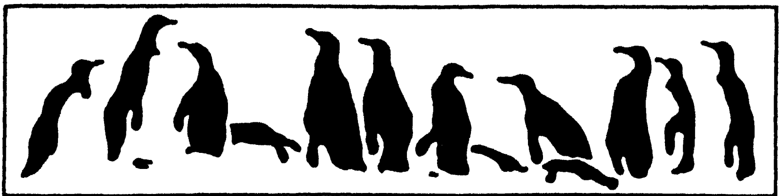
UNIT II

Distributional Biology

GEOGRAPHIC DISTRIBUTION OF ORGANISMS
LIFE ZONES
MOUNTAIN-TOP BIOLOGY
REGIONS OF THE WORLD



Preview

Some day, then, we must explore this living world—to the far ends of it—at least some part of it. We shall sail the seven seas, cross far-flung deserts, toil to the tops of the highest peaks—or, at least, find strangers at our doorsteps and in the weed lots and along the daily paths which we travel.

And then, if we know their nationalities, the part of the earth from which they have come, by what means they have travelled, how they have managed to establish themselves in this new land, and whether they will make friendly or unfriendly neighbors for us—if we know these things, even this part of the world in which we are living will become more interesting.

In this day of low-price cars and good highways, every boy and every girl may expect to travel, at some time, into parts of the world that will be new to him—or her. Then what you have learned about the way in which plants and animals are distributed will make your journey interesting in ways which the average sight-seeing tourist will never know. In addition to the people and all of the man-made things which interest most travellers, you will find a world full of other living things to look at, to investigate, to understand, and to remember.

Thus, it seems worth while for all of us to learn something of distributional biology.

CHAPTER VII

GEOGRAPHIC DISTRIBUTION OF ORGANISMS

Come, then, with me. Let us travel here and afar. Let us see what we may learn about the distribution of these organisms we are collecting.

Ranges

But if we go very far from the region in which we have been living, we immediately find that different kinds of plants and animals occur in the different parts of our country. Indeed, you have been, at least in a way, aware of this fact before. You have known that the polar bears and musk-ox of the Arctics do not occur in Indiana or California or Florida; that crocodiles in the United States are restricted to southern Florida; that big trees occur only in California; and that each part of the world has its own plant and animal products which it must supply if the rest of the world is to have them. Our taxonomic explorations show us that every other species of plant and animal is similarly restricted in its geographic distribution—restricted in many cases to a very small part of the world about us.

The geographic area over which a species occurs is known as its range. Of course, no species is represented by individuals in every foot of its range, but it will occur often enough to allow us to think of it as inhabiting the whole of that area. We may quite properly say, for instance, that moose range throughout the Northeastern United States and adjacent Canada, even though we might travel for many miles in that region without ever meeting one of those animals.

Boundaries.—The boundaries of these ranges are often quite definite. The Androscoggin River in southwestern

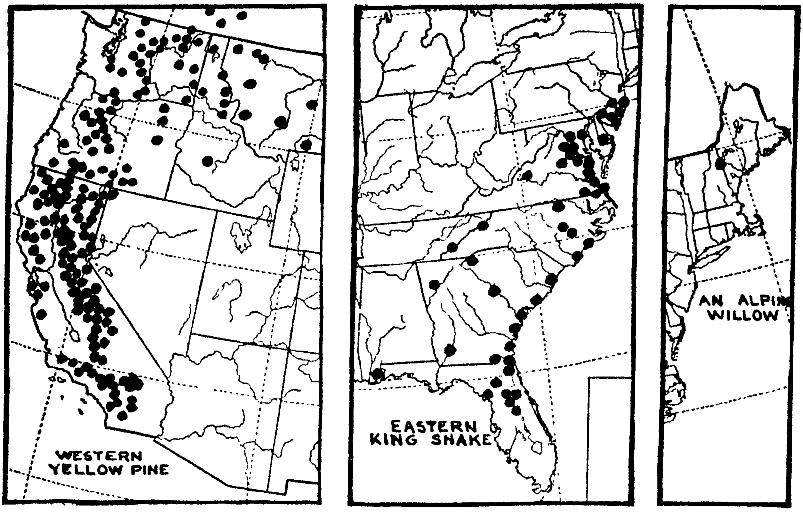


FIG. 71.—RANGES ARE LIMITED, VARYING IN SIZE, LOCATION, AND SHAPE

Each dot represents a locality from which specimens have actually been collected.

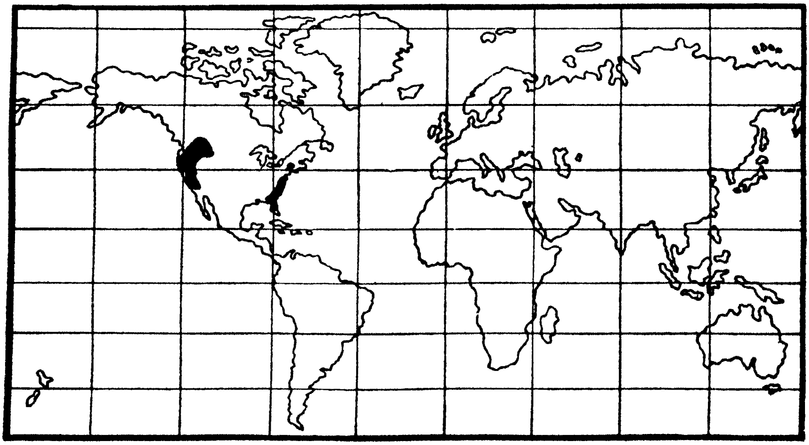


FIG. 72.—EACH RANGE REPRESENTS A SMALL PART OF THE WORLD

Ranges of the same three species shown in the preceding figure.

Maine is the more or less absolute, southern boundary of the ranges of many of the animals of northern Maine and Lower Canada. The limits to which trees extend toward the tops of very high mountains are sometimes marked as sharply as though a plough had been driven about the mountainside. The ranges of many of our western plants and animals may be as sharply bounded where the bases of mountains come out onto the deserts.

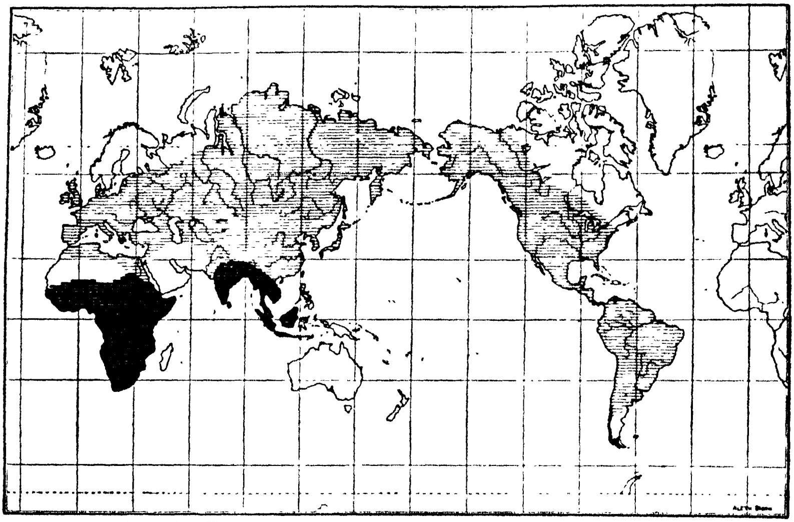
More indefinite limits to ranges are found wherever there are no good natural formations (such as rivers or high mountains) to act as the barriers to the spread of a species.

Ranges are more sharply marked for some species than for others. Species that move about easily, things like birds and mammals and plants with winged seeds, straggle across the boundaries of their ranges more often than organisms that have no special means for travelling.

Continuity and Size of Ranges.—Ordinarily ranges are continuous stretches of country, but there are a few cases of discontinuous ranges which are broken up into distinct, widely separated parts. Thus, some of the insects of the White Mountains of northern New Hampshire are also found on Pike's Peak in Colorado, and not at any point of country between those two places. But such discontinuous ranges are the exception.

Ranges differ considerably in size. Some of them are very large. For instance, many of the plants of southern New Hampshire range continuously into Kansas. There are even some species which are *cosmopolitan* in their ranges, occurring more or less everywhere around the world. This is true of such forms as the house-mouse and rat, the roach, the house fly, and the common plantain which is a weed on our lawns. Most cosmopolitan things live in close contact with man, and become world-wide in distribution because they follow him wherever he goes. But most species have smaller ranges, some species even being confined to areas not more than twenty or thirty miles in diameter.

Fixity of Ranges.—Of course, the range of a species may change in size in the course of a few years, for every organism is continually tending to extend its range. But its enemies restrict it and often exterminate it from new territories. The forces aiding the distribution of the species and those that are preventing its spread often produce a balance, and the ranges of many species, therefore, remain more or less fixed.



Courtesy Amer. Mus. Nat. Hist.

FIG. 73.—A RANGE THAT HAS DECREASED IN SIZE
Former distribution (shaded) of the elephants and mastodons of the geologic past, and present distribution (dark shaded).

That ranges sometimes become smaller is well known. Man himself has been responsible for the restriction of the ranges of the bison, the moose, the holly used in Christmas decoration, and many of the more attractive wild flowers.

That some ranges increase in size may be observed easily enough in the course of a few years. All of the imported insect and weed pests are species with spreading ranges.

The rate at which a range enlarges varies considerably with different species. The European cabbage butterfly spread from the Atlantic to the Pacific coast of North America between 1868 and 1910. Within the very same years, the gipsy moth, introduced at Boston, spread only half way across the state of Massachusetts.

Organic Barriers and Aids

But, as we have said, every organism tends to spread beyond the boundaries of its range. Plants scatter their seeds far and wide. Animals fly and crawl into regions never before visited by their kind. There are many things that aid them in their distribution, and barriers that prevent them from travelling too far.

First among these barriers and aids are living organisms themselves. They are the *organic* factors of distribution.

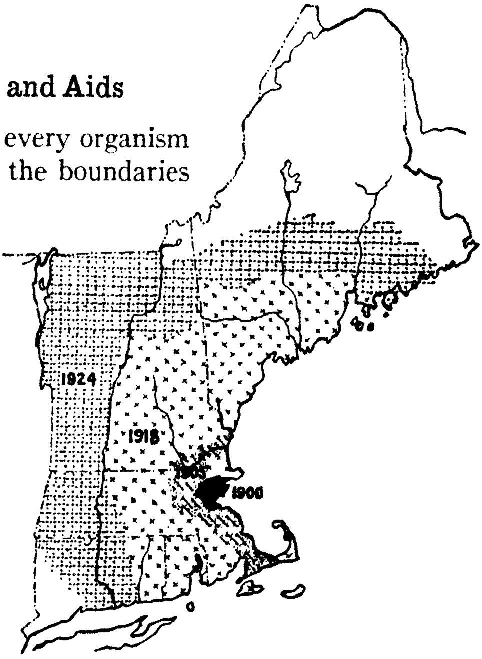
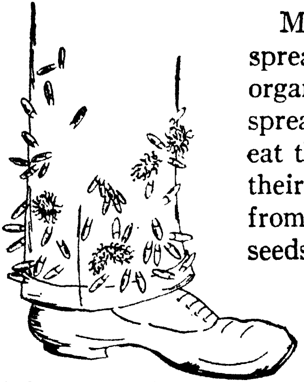


FIG. 74.—THE ENLARGING RANGE OF THE GIPSY MOTH

The very nature of the species will help determine its chances for spreading afar. Animals that have the best means of travel, such as strong wings or legs or fins, are the ones most likely to become widely distributed. Animals that crawl or that fly only weakly will probably stay within more fixed ranges. Plants with winged seeds or long runners, and those that reproduce by means of shoots, are more likely to spread farther than plants that have none of these special structures.

Organisms that feed on a variety of food, instead of restricting themselves to some special diet, and organisms that are not too particular about temperature and moisture and sunshine conditions, or that are not so tender and attractive to other creatures that they are in continual danger of having their heads eaten off, are also among those likely to become well-known globe-trotters.



M. L. Voorhees, Del.

FIG. 75.—BOOTLEGGERS

Many organisms are assisted in their spread by the unwitting aid of other organisms. Brightly colored berries are spread by birds that are attracted to them, eat them, pass the seeds uninjured through their digestive tracts, and drop them miles from their sources. Insects and weed seeds become attached to the hair or wool of passing animals, or become stowaways in some man's auto, a freight car, or a steamboat, and are carried far beyond the limits of their old ranges. Cattle ticks get from field to field by way of the cows to which they attach themselves. Ticks can be kept out of any field by preventing tick-infested cows from entering.

But there are plants and animals that are barriers to the distribution of other species. They are the head-hunters in search of food. They destroy intruders into their domains, and even crowd them back in their own ranges.

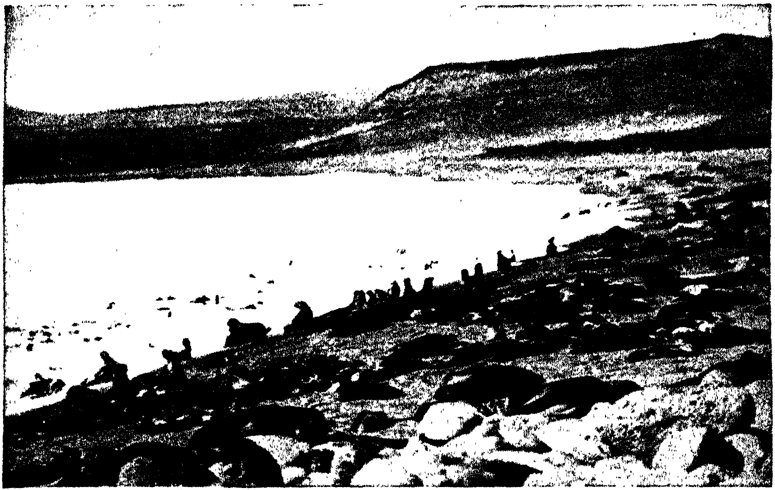
Each plant or animal is thus a barrier or an aid to the distribution of every other plant and animal.

Geographic Barriers and Aids

Such geographic features as land and water and deserts and mountains are factors in distribution, serving as barriers to the spread of some species, and as aids to the spread of others.

Water plants and animals find rivers and lakes and oceans very convenient for travelling. Consequently the ranges of aquatic forms are often large, some ocean-inhabiting species even occurring around the world.

Land inhabitants, on the other hand, spread most easily where there are continuous stretches of land. For them large bodies of water are barriers. Only occasionally do the seeds of plants, and pieces of roots and of stems, float across an ocean. The salt water of the ocean, the breadth of the ocean, and the strong winds to be found there forbid the migration of most land animals and plants over the open waters.



Courtesy U. S. Bur. Fisheries

FIG. 76.—SEALS ON THE ALASKAN SHORE

Even such water inhabitants never get far up onto the land. The land is a barrier to their distribution.

The organisms found on an island or on a continent surrounded by water stand few chances of visiting or of receiving visitors from other lands. The strangest plants and animals which we know are those found on the most isolated islands, for they have had the least chance to cross with species of other regions.

Climatic Barriers and Aids

The climatic conditions of a region also serve as barriers or aids to the distribution of organisms. When we speak of the "climate" of a region we refer to its temperature, humidity (the amount of moisture in the air), rainfall, wind, and sunlight. Each kind of organism can exist only where there are certain, very definite climatic conditions. No Arctic plants or animals live in Florida, chiefly because of temperature conditions. Most swamp inhabitants cannot live on dry roadsides because of moisture factors. Species of deep, shaded woodlands cannot grow in the sunshine of an open meadow. Most plants cannot survive the winds met with along ocean coasts and on high mountains.

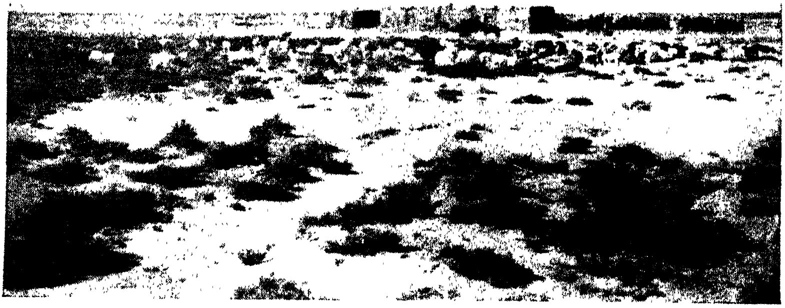


FIG. 77.—THE DESERT AS A BARRIER TO DISTRIBUTION
Few organisms beyond a few plants, the goats, and an occasional ranchero are able to survive such arid regions. In the state of Chihuahua, northern Mexico.

Changeable, fickle climates are severe on plant and animal life. Even temperatures, whether high or low, do not kill as often as sudden changes. Many plants do not grow well in the highly changeable climate of the Middle West, although they prosper both farther north and farther south where the climates are more even. Plants and cold-blooded animals can be frozen without being killed when the changes of temperature are made more gradually than they occur in Middle Western areas.

At higher elevations in mountain country, the climate is often of the most extreme sort, as we shall see in a later chapter; and most organisms are not able to live under such conditions. Mountains are, therefore, the most effective of barriers to the distribution of lowland species.

Geologic Factors of Distribution

Just as conditions today control the distribution of the species of today, so the conditions of the remote past of millions of years ago controlled the distribution of the then-existing plants and animals. Sometimes the present-day descendants of the ancient species have about the same ranges as their ancestors had.

For instance, many of the plants of the sandy lowlands of the Atlantic Coastal Plain, range continuously from Georgia to central Jersey, and then occur nowhere north of that point except on Long Island and Cape Cod and in Newfoundland. At present there are no sand countries between those outlying stations by which the plants could have spread northward from New Jersey, but the geologists, who are the students of the structure of the earth, tell us that long ago there was a continuous stretch of such lowland from New Jersey to Newfoundland. The northward section of the Plain is now sunk under the ocean except at the few points mentioned as inhabited by the descendants of the ancient species.

As another illustration of present-day ranges whose limits are the result of conditions that existed in the geologic past, we may note that there are many plants and animals in the Pacific Coast area of the United States and Canada which have their closest relatives in Europe or in more northern

Asia. This is explainable, geologists tell us, because there were, in a former geologic period, continuous land connections between Siberia and Alaska. Moreover, at that time the climate in that part of the world was not severe, and many kinds of plants and animals were able to travel from Europe and northern Asia into western North America. Today the ocean waters of Bering Straits and the present cold climate of Alaska make it impossible for most Asiatic and American species to travel from one continent to the other. The relatives of European things which we find in northern California, Oregon, and other western parts of North America must have made their great journey at some time in a by-gone geologic age.

In every case, then, there are many factors operating to restrict each organism to the particular, small part of the world in which we find it.

SUMMARY

1. Different kinds of plants and animals occur in different parts of the world. Each species is restricted to a limited geographic area which we call its *range.*
2. The boundaries of ranges are often quite sharply defined. More indefinite limits to ranges occur with species that have special means for travelling.
3. Ranges are usually continuous stretches of country, but there are cases of discontinuous ranges.
4. Ranges are usually small. A few man-distributed species are cosmopolitan.
5. Ranges may become larger as the species extends its range or smaller as it is exterminated from a part or the whole of its former range. Sometimes ranges enlarge rapidly, sometimes very slowly, and often they remain more or less fixed.
6. The very nature of the species, and the other plants and animals with which it comes in contact, are the organic barriers or aids that prevent the species from spreading, or which help the species enlarge its range.
7. The geographic barriers and aids to distribution are land, water, deserts, etc. Inhabitants of islands in an ocean are often strange species

because they have been so thoroughly prevented from coming into contact with other organisms.

8. The climatic barriers and aids are temperature, humidity, rainfall, wind, sunlight. Fickle climates are severe on plants and animals.

9. The conditions of past geologic ages have had considerable effect on the present-day distribution of plants and animals.

DEFINE

Range	Aids to distribution
Continuous range	Organic factors of distribution
Discontinuous range	Geographic factors
Cosmopolitan	Climatic factors
Barriers to distribution	Geologic factors

PROBLEMS

1. Be prepared to give a definite case (*i.e.*, by telling of the case of a particular species of plant or animal) that illustrates each of the principles given in the 9 paragraphs in the above summary of this chapter.

2. Which of the following would you expect to have large ranges: a dandelion, a snake, a rabbit, a rat, a cockroach, a nut tree, a thistle? In each case, what are the organic factors that aid or prevent their wide distribution?

3. Would you expect to find many North American plants and animals in South America, Europe, or Australia? Or European things in Australia, Asia, or South America? Explain your answers.

4. Can you name some of the geographic and climatic factors that favor or prevent plants and animals from ranging into your own region from the country north, south, east, and west of you?

5. Make a list of the chief barriers and aids to the distribution of man, classifying them as organic, geographic, climatic, or geologic factors of his distribution.

6. List the barriers to the distribution of marine plants.

7. Make a list of the various means by which plants extend their ranges—their means of travel from one region to another.

8. Can you name any kind of plant or animal which occurs in your state and nowhere else in the United States?

CHAPTER VIII

LIFE ZONES

One thing that our explorations show us is the fact that many of the species of a given region may have about the same ranges. Plotted independently upon maps, the boundaries of the several ranges would more or less coincide (completely overlap). This means that the distribution factors acting upon any one species have about the same result as they have upon some of the other species of that region.

Life Zones

An area which represents the common range of a large number of species, plant and animal, is called a *life zone*. In that same area we always find species whose ranges do not coincide, and many of the species that enter the region have ranges very largely outside of that life zone; but if there is any large number of species with a more or less common range it is profitable to think of the common range as a life zone.

We speak of all the animals of any particular area—of a life zone for instance—as a *fauna;* and of all of the plants of any area as a *flora*. The fauna of any part of a life zone will be much like the fauna of any other part of that zone; and similarly the flora will show some uniformity throughout a life zone. Nevertheless it must be said again that there are many species in any life zone which do not have ranges anything like the range of the species by which we have defined the zone.

Since no two species have precisely the same ranges, the boundaries of life zones will always be more or less indefinite, with some of the species falling short of the boundary which we draw on our map, and other species extending beyond for miles or scores of miles or even some hundreds of miles in the case of the less sharply defined life zones.

The boundaries of life zones are most sharply defined when there are rivers, lake shores, mountains, deserts, or other such geographic formations to limit the ranges of a large number of species. Usually life zones have more indefinite boundaries.

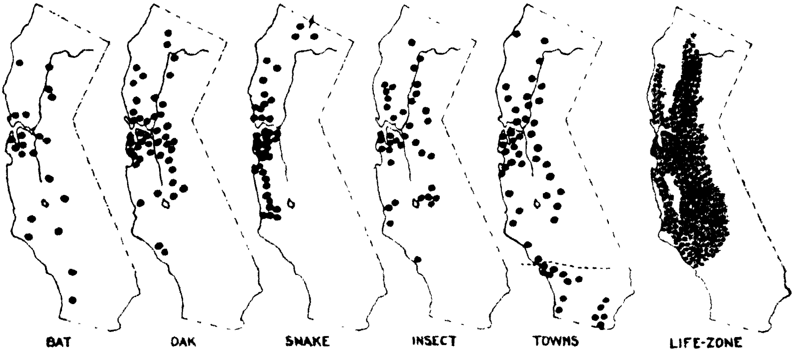


FIG. 78.—RANGES OF FIVE ORGANISMS, AND THE LIFE ZONE TO WHICH THEY BELONG

Western red bat, valley oak, coast gopher snake, a gall wasp, and the human population. No two ranges are exactly alike, but the life zone includes most of these and other ranges.

The scientific study of life zones, and the exact determinations of their boundaries must be made by the taxonomist who travels abroad, by train, by auto, by horseback, or by foot, taking samples of what he finds as he goes along. He collects at as many different localities as possible. He takes the specimens back to his laboratory, and there he and other specialists determine what the correct names are for the species that come from each locality. Unless this taxonomic work is accurately done, we can reach no true conclusions as to the distribution of any species or of the life zone to which it belongs.

Of course, no scientist ever gets specimens from every one of the localities in any zone, and he can never be quite positive of the boundaries. We do not yet know very much about the distribution of even common species, just because it is such a difficult thing to collect at enough places. This explains why it is that biologists are not agreed on the number of life zones that should be recognized even in our own country. You will find some books listing only fourteen life zones for the whole United States, but the more recent taxonomic work seems to indicate that we should recognize some fifty or more in the country. Every boy and girl who learns of a scientist who is making a study of the distribution of a particular group of organisms could help by collecting material from his or her own locality. Carefully label it with the name of the locality (indicating the distance from the nearest post office or other

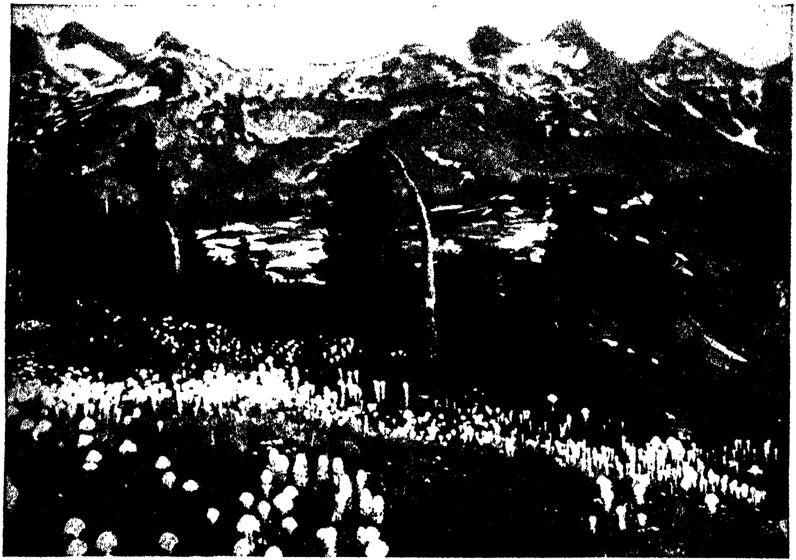


Photo by Asahel Curtis, Seattle

FIG. 79.—THREE LIFE ZONES ON MT. RAINIER

Forested slopes, Alpine meadows in flower, and snow- and ice-covered summits.

definite landmark), give the date of collection, and carefully pack the material in sending it to the specialist.

Transition Zones

Any region which receives a large number of stragglers from each of two near-by life zones is known as a transition zone.

Usually transition zones are only a few miles wide. The region between El Portal, at the entrance to the Yosemite Valley, and the Valley itself, five or six miles away, is the transition area between the great zone that extends for five hundred miles in Southern California, and the zone that covers most of the slopes of the mountains of Central California. A very much wider transition area, probably the widest in the United States, extends between Connecticut and southern Maine. In it are to be found species from northern Maine, and species from the southern zone which extends from Connecticut into western Georgia.

On the whole, transition areas are narrow more often than might be expected.

American Life Zones

Now, in this age of long-distance automobile travel, you may hope to go some day to regions that belong to life zones totally distinct from the one in which you now live. Depending upon the more conspicuous plants, and upon some of the birds and other animals which may be identified most easily, you may recognize the boundaries of some of the life zones into which you travel, especially if we now give you some notion of what the United States is biologically. I know of nothing which will do more to make the world interesting to the traveller. No corner of this globe, no bit of country can be so remote, so barren, so devoid of human creations, that it will not have its biologic interests for one whose eyes have been taught to see, whose mind can perceive the peculiarities of the plants and animals of each region into which he travels.

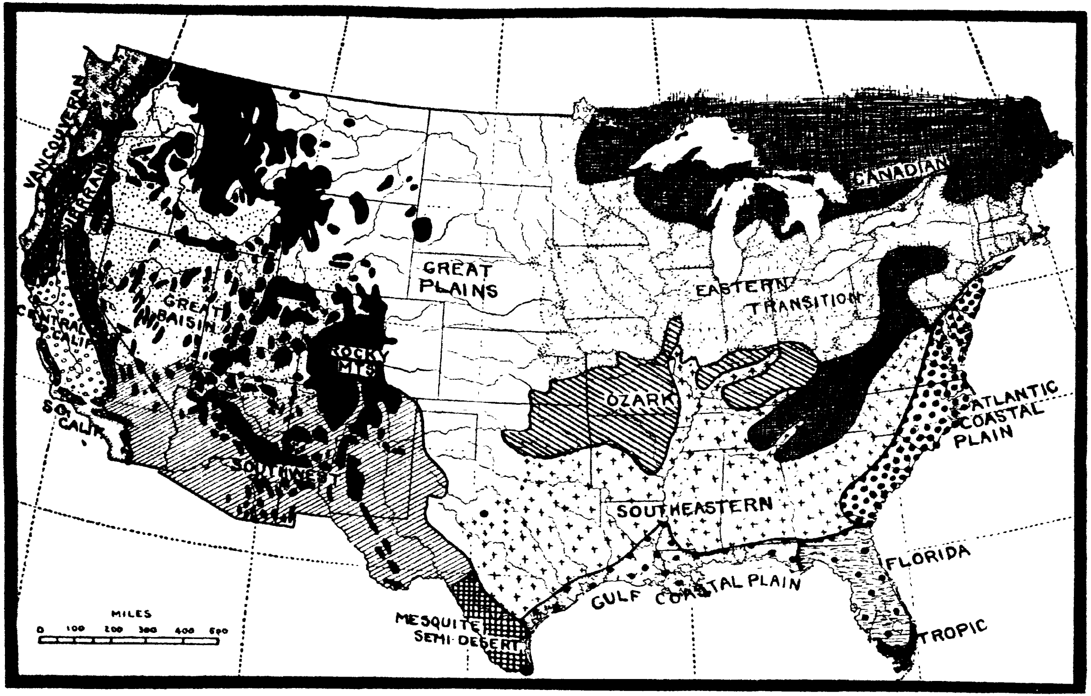
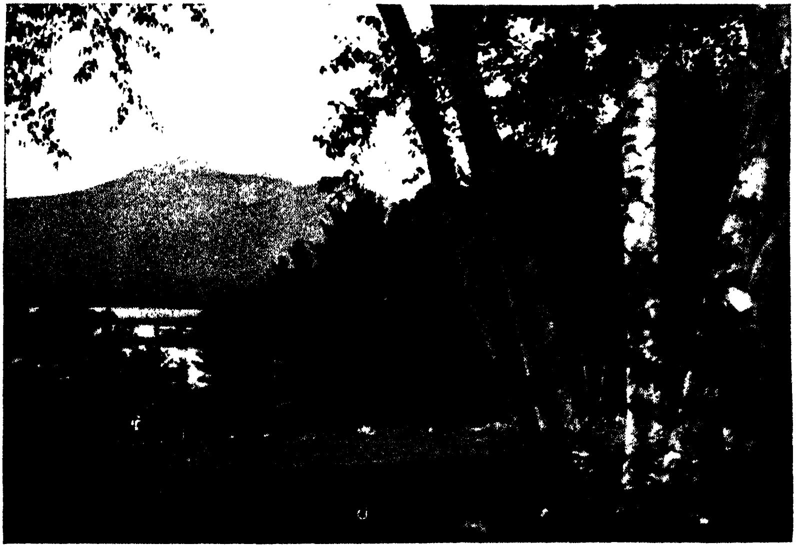


FIG. 80.—AMERICAN LIFE ZONES

In each of these areas there are many plants and animals not found in any other area; but there are many species (perhaps the majority) whose ranges do not coincide with these areas. Transition areas, wide-spread in nature, not shown on this map.

You should realize, moreover, that there is probably no single country in the world which contains as many different faunas and floras as the United States. This is because there are so many different kinds of country to be found within our boundaries. The traveller from England, crossing Europe and the whole of northern Asia, arriving after a journey of some seven thousand miles in the islands of Japan, would have crossed possibly no more than a half dozen life zones. In half that distance in the United States one might easily touch more than thirty.



Courtesy Shorey Studio, Gorham, N. H.

FIG. 81.—CANADIAN ZONE FOREST

Paper birch and white pine in northern New Hampshire.

Come, then, with me across our country. In the limited time at our disposal, in our first introduction to biology, we shall not be able to consider all of our American life zones, but we shall discuss at least some of the more important of them.

Canadian Zone.—Beginning at the northeastern corner of the country, we meet with great evergreen forests extending from Maine, across all of northern New England, northern New York, Michigan, and Minnesota, and northward into southeastern Canada. Look at the map of life zones, page 124; learn what you can about the location of this biologic area. These forests belong to what is called the Canadian Zone. These are the "north woods" of the summer campers and the "big timbers" of the lumberman. It is a land of lakes and streams for the canoeist, a country of cool summers, a land that is snow-bound in its long winters. Here grow pines, hemlocks, firs, and spruces. Here are the homes of the eastern jack rabbits, the nesting grounds of many birds that occur southward only in migration, and the regions where black flies and midges abound in early summer.

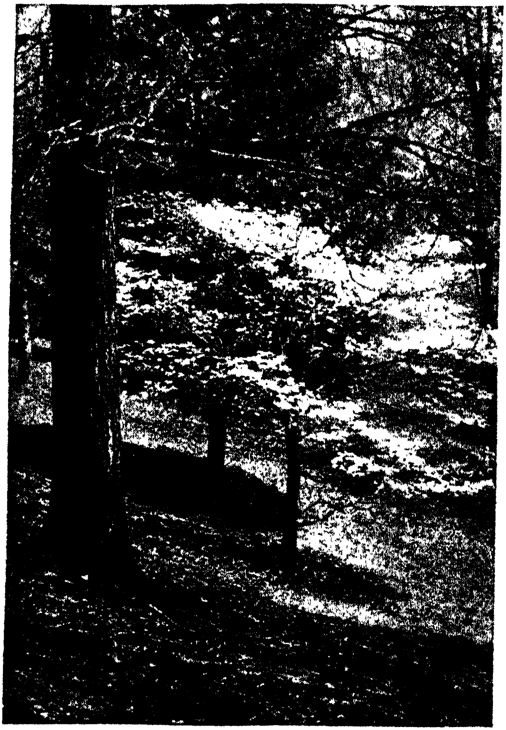


Photo by O. W. Price. Courtesy U. S. Forest Service

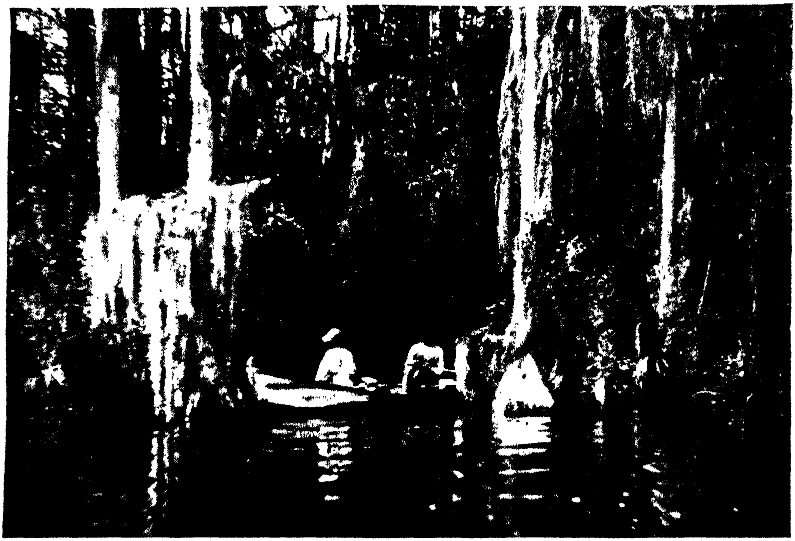
FIG. 82.—EASTERN TRANSITION ZONE
A bit of spring woodland, dogwood in flower.

Eastern Transition Zone.—This zone, extending from New England, New York, and southern Michigan to the Ohio River, western Iowa, and Missouri, is a country of relatively uniform geography, with few and mostly low mountains, and with large areas of flat land. It contains no deserts. The boundaries of this zone are in consequence not sharply defined. One might travel from this area into any of the areas to the north, south, east, or west, without realizing he was passing from one life zone into another until he was well along into the new life zone. Most of this region is covered with deciduous (not evergreen) forest, much of which is now thin and depleted, for this is the part of the country which has the largest human population and the largest proportion of cultivated land in North America. It is, on the whole, a region of temperate climate, with rather severe winters and hot summers, especially inland in the northern "Middle West," which is part of this area.

The western part of this area, from northwestern Indiana and across Illinois into Iowa, has only small stands of scattered woodland, with more or less extensive stretches of flat *prairie* lying between. The prairies differ from the Great Plains to the west not only in having some woodland, but also in having fairly moist soil that is very rich for agricultural purposes. There are many plants and animals of these prairies that do not extend farther east than northern Indiana, or into the wooded areas anywhere in this zone. The prairies, therefore, may be thought of as a sub-division of the eastern transition zone, or even as a distinct life zone interwoven through the western part of this transition zone.

All of this eastern transition zone was covered with ice during the Great Ice Age, many thousands of years ago, as we shall note again, farther along in our studies. During this Great Ice Age the climate of this region was so cold that only Canadian Zone and more northern species lived here. As the ice sheets melted away, most of the more northern things retreated to the north; but a few of them still remain here, together with the more southern things that have now returned to the area. This is one reason why this is truly a great transition zone between the Canadian zone and the several zones to the south.

Ozark Life Zone.—The well-forested hill country of southern Missouri and of Arkansas north of the Arkansas River is the heart of an area which has species so closely related to those of the eastern transition zone that only the expert taxonomist would notice many differences. Oak and hickory are the most prominent trees of the forest. The area extends westward into Kansas and eastward through southern Illinois and Indiana and across much of Kentucky.



Courtesy H. H Brimley, N. C. State Mus.

FIG. 83.—AN ATLANTIC COASTAL PLAIN SWAMP, NORTH CAROLINA

Atlantic and Gulf Coastal Plains.—The southeastern coasts of the United States, from southern Jersey to Florida, and along the Gulf to southern Texas, are forested swamp, open sand-plains, and salt-marsh countries, belonging to three or more life zones. These are shown on the map as the Atlantic Coastal Plain, Gulf Coastal Plain, and Southeastern Life

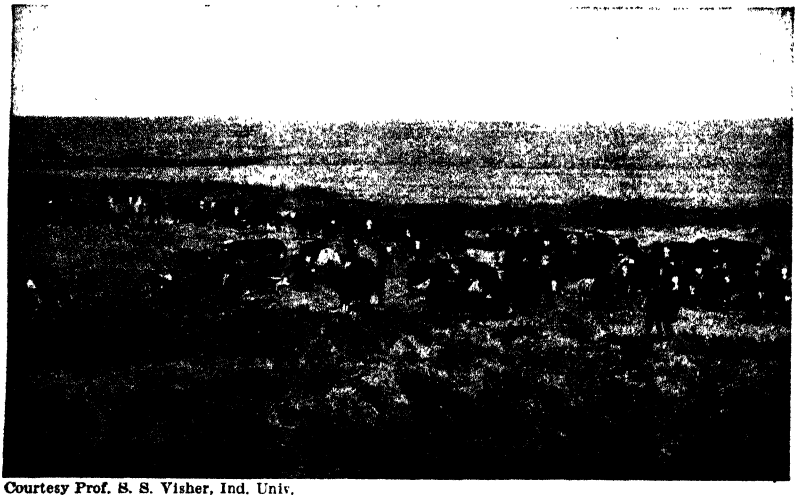
Zones. Deciduous oak and hickory forest is common farther inland. Pines and scrub oak are abundant nearer the coasts. The coastal flora is on the whole more luxuriant and the fauna richer than the fauna and flora of any other part of the United States east of California, unless it be in the adjacent life zones of Florida. In spite of this the taxonomy of the plants and animals of the region is about as poorly known as that of any remote mountain area of the western United States. This is because of the former difficulty of travel in these areas of salt marsh and river swamp; but with the advent of modern roads the taxonomists are undertaking more extensive studies of the region.

Many of the plants and animals of these areas extend inland to higher ground which is no longer the true Coastal Plain of the geologists; but the Coastal Plain life zones extend inland to the Appalachian Mountains and to the Ozark highlands, and in Texas to the treeless areas of the great plains.

Florida.—This state is distinct from the other coast regions. Its temperature is semi-tropic, and it has an abundance of water. The whole state lies so nearly at sea level that drainage is poor and swamps abound, forested sometimes with pine, cypress, and palmetto, sometimes with live oak and a semi-tropic jungle. Many of the swamps are open except for a luxuriant growth of grass. South of Miami, at the southern tip of the peninsula, there is a life zone which is more truly tropic than the rest of the state. In this area occur the famous royal palms, tropical orchids, some of the very primitive seed plants called cycads, and numerous things of West Indian or Mexican origin. Bananas, pineapples, and coconuts may be cultivated in the region. Except for a small bit of country about Brownsville, Texas, this is the only part of the United States that approaches the true tropics in character.

Mesquite Semi-Desert.—The southernmost portion of Texas, although fronted by a narrow coastal strip that is more nearly Gulf Coast swamp, gives way to a sandy semi-desert region inland. The area is densely enough covered with a tall shrub or small tree called mesquite, and with grasses suitable for cattle pasture; but it lacks the deciduous forests typical of most of the eastern United States. Toward the west this mesquite area gives way to the still more arid, more truly desert areas of West Texas and the Southwest.

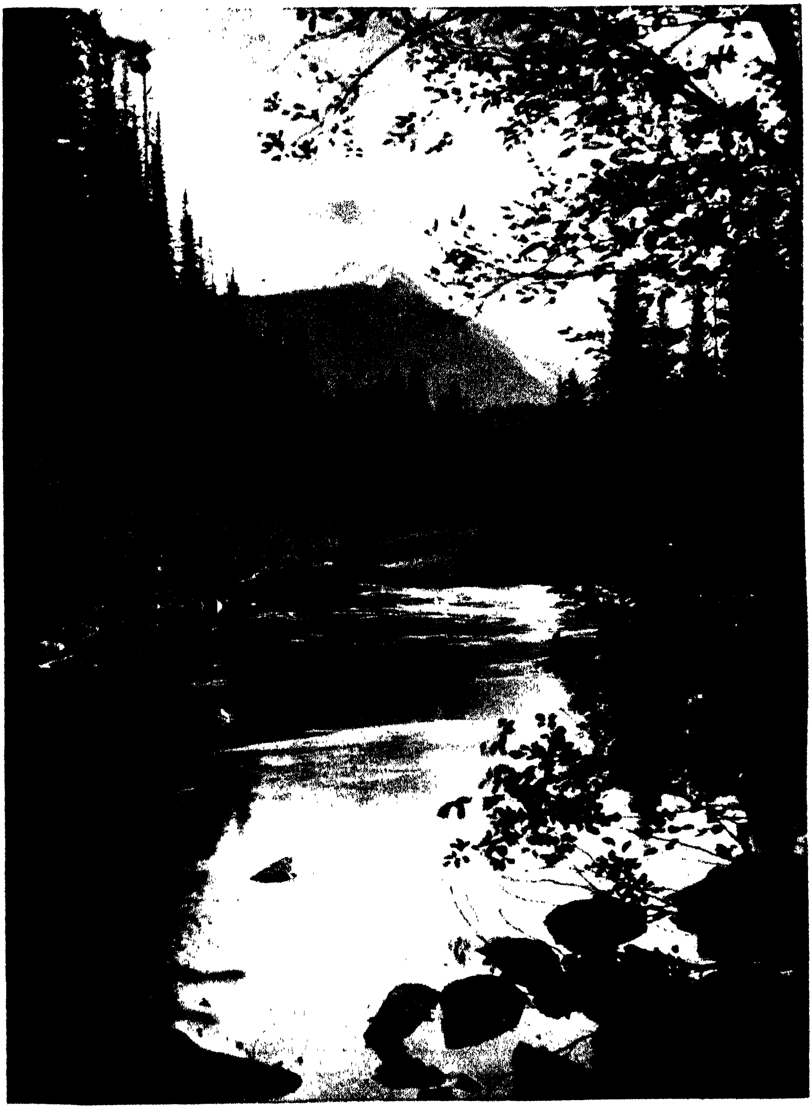
Great Plains.—An interesting line, running north and south near the hundredth meridian, rather sharply divides the whole of the United States into an East and a West. East of the line the rainfall is distinctly greater than west of it, but it is not at all certain that that is the only thing that establishes this boundary.



Courtesy Prof. S. S. Visher, Ind. Univ.

FIG. 84.—THE GREAT PLAINS IN SOUTH DAKOTA

The Great Plains, lying between this line and the Rocky Mountains, are treeless except in the river bottoms, and they are mostly dry, sometimes alkaline, originally bearing sparse or scattered grasses. The variety of plant life and consequently of animal life is limited, and aside from the low grasses the only conspicuous plants are such shrubs as yucca and sage-brush. The region is fertile enough under proper meth-



Copyright Asahel Curtis, Seattle

FIG. 85.—IN THE NORTHERN ROCKIES, MONTANA

The forests contain western species of fir, spruce, and pine.

ods of dry-land farming. It is, however, arid enough to have discouraged any extensive settlement by man.

The Great Plains were the ranges of tremendous herds of buffalo in pioneer days, and they constitute good cattle country today.

Rocky Mountain Areas.—The Rocky Mountains, with connecting ranges that extend from Montana and Idaho into northern Arizona and New Mexico, so cut up that part of the country as to produce a large number of small life zones with more or less distinct faunas and floras. In this region it is often possible for one to travel through several zones in a day, especially if he is climbing from one elevation to another. The lower mountain slopes are mostly barren, the higher elevations are forested with aspens and evergreens, and the highest peaks are again mostly bare, some of them being snow-capped during most of the year.

The southern portion of the Rockies receives more rain than the northern portion of this mountain system; and it is in southwestern Colorado, northern New Mexico, and northern Arizona that the densest evergreen forests, richly clothed with such things as yellow pine, Colorado blue spruce, and white fir, reach their prime development.

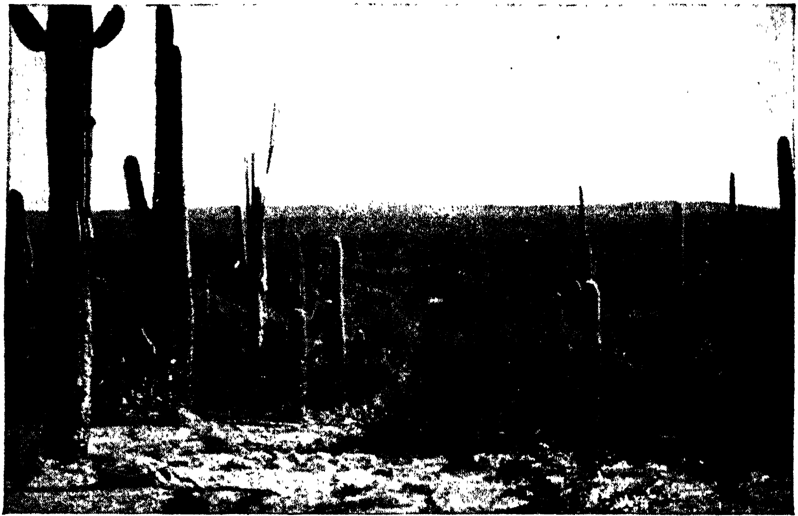
Black Hills.—Well removed from the other mountains of this area, the Black Hills of South Dakota and of the adjacent corner of Wyoming rise as well-forested mountains surrounded by barren plains, like an island mass standing out in an ocean. As on an island, the plants and animals of this area are completely isolated from the typical Rocky Mountain species, and although they represent related species they are quite distinct things, as biologists are only beginning to realize. Many of the species are indeed more or less intermediate in character between Rocky Mountain species and species of the forested country away to the east.

Utah.—The mountain country of Utah is in many ways part of the Rocky Mountain system; but there are barren and alkaline deserts in eastern Utah and western Colorado, and at no place do the main ranges of the mountains of Utah connect with the main ranges of the Rockies. Just as with the Black Hills, the isolation of this Utah mountain area has allowed perfectly distinct species to develop there. We have heretofore failed to realize that these species of the forested, higher levels of Utah were so different from those found anywhere else in the United States. Here is one of the promising regions for biologic exploration. In the extreme southwestern corner of Utah, in the region about and west of the wonderful Zion National Park, there are plants and animals that show a remarkable relationship to the things of southern California, rather than to the fauna and flora of the Rocky Mountains.

Courtesy U. S. Dept. of Agriculture

FIG. 86.—A GREAT BASIN DESERT IN NEVADA

Great Basin Desert.—Between the Rockies and the mountains of California and Oregon there lie extensive deserts and low mountain countries containing several life zones. This was the "Great American Desert" of the pioneers, a region so arid and barren that it was first crossed by white man hardly more than ninety years ago—still within the lives of living men. There are as few species of plants and animals on these deserts as one may find in any part of the United States. Southward the deserts are low, in some places below sea level. Here the waters originating in the adjacent mountains accumulate in lakes which, because they never drain out, have become as salt as the sea. Consequently plants similar to those of the ocean coasts are to be found on the shores of these salt lakes. Northward in Idaho and eastern Oregon the deserts become 4,000- to 7,000-foot plateaus, but these are still as barren and arid as any portion of the Great Basin.



Courtesy Forrest Shreve and Carnegie Institution

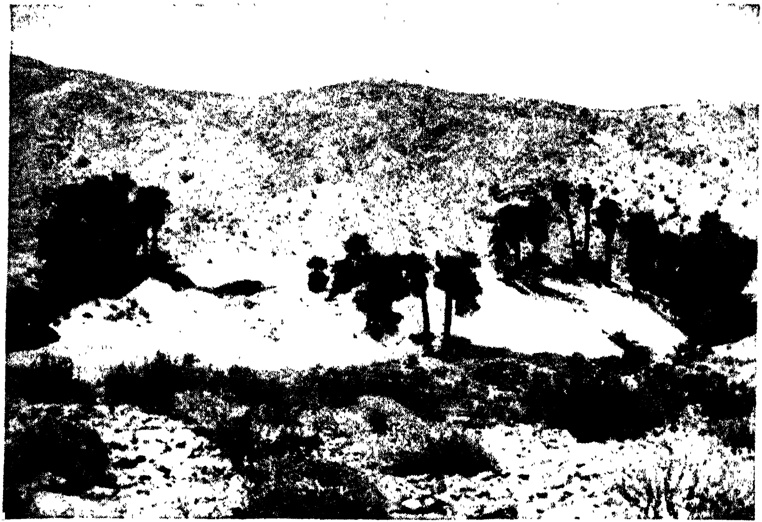
FIG. 87.—IN THE SOUTHWEST, SOUTHERN ARIZONA

Southwest.—To the biologist the Southwest is a land of mystery and endless delight. From West Texas, across New Mexico and Arizona, and on into southeastern California there lies a succession of deserts and isolated mountain ranges, no two of them quite alike in their plants and animals. Even the most unobservant traveller might see several life zones in this region. Some of the deserts are sandy, wind-blown, and almost barren. The desert of southeastern Arizona, on the other hand, has a rich growth of cacti and similar things which often become higher than a man's head. The mountains, rising abruptly from these deserts, have distinct faunas and floras at the different altitudes, and many of them are crowned with dense, evergreen forests. We shall see more of these in our next chapter.

Sierran Zones.—Rising majestically on the California-Nevada boundary, the Sierra Nevada, with its extensions into Oregon, stands as the highest and most extensive continuous range of mountains in the United States. The western slopes of these mountains are heavily forested, bathed by the moisture-laden winds from the Pacific Ocean. This is the home of the sugar pine, of the big tree, and of other species which make up a dense, evergreen forest. On the other hand, the clouds drop all of their water before they climb the crests, and the eastern walls of the range are nearly as dry and barren as the deserts that lie at their bases. There are no low passes in the body of these mountains, and they are as effective barriers to the east and west distribution of plant and animal life as anything in North America. Very few of the Pacific Coast species occur east of the range, although farther north, in Washington, such river canyons as that of the Columbia allow some of the Rocky Mountain species to spread westward to the ocean.

Pacific Coast Zones.—The Pacific Coast of the United States has a dozen or more distinct life zones. Much of Southern California was originally semi-desert, although parts of it are now luxuriant with blossoms and fruits because of man's industry in irrigation. Central California, just west of the Sierras, has low, marshy, open areas (the San Joaquin and Sacramento Valleys). West of this, rising abruptly from the sea, are the beautifully forested Coast Ranges of Southern and Northern California, separating the central valleys from the sea. It is in the Northern Coast Ranges that the wonderful redwood (Fig. 5) reaches its best development.

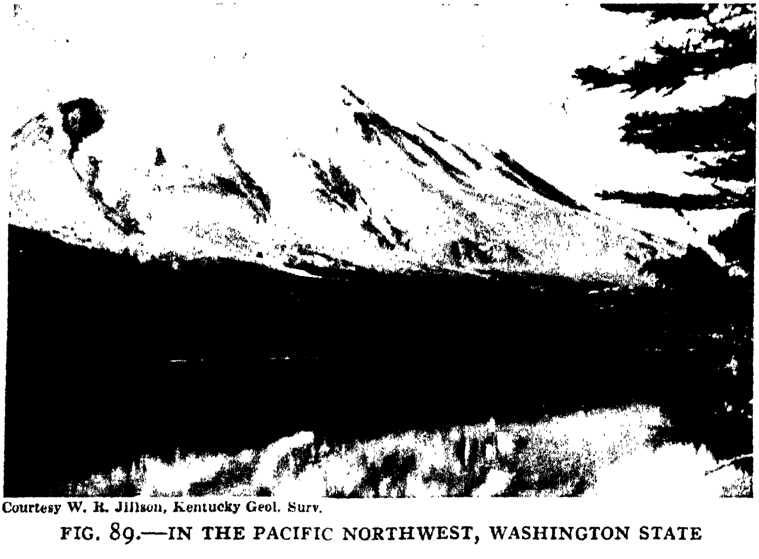
Northern California and western Oregon are more generally mountainous and luxuriant with evergreen forests. This is



From the Flora of California. Courtesy W. L. Jepson

FIG. 88.—A SOUTHERN CALIFORNIA DESERT

Fan palms near Indio, California.



Courtesy W. R. Jillson, Kentucky Geol. Surv.

FIG. 89.—IN THE PACIFIC NORTHWEST, WASHINGTON STATE

the Vancouveran Zone shown on our map. It is a region of mild winters and cool summers. It extends northward along the Pacific Coast of Canada and even onto the coasts of Alaska. This region receives a heavier rainfall than any other part of the United States. It is in this area that we find plants and animals which have European and Asiatic relationships, as we pointed out in our previous chapter.

SUMMARY

1. An area which represents the common range of a number of species is a life zone. The boundaries of life zones are always indefinite, being best defined by such geographic features as rivers, mountains, deserts, etc.

2. Accurate knowledge of life zones depends on the work of the taxonomist who collects from many localities and determines the correct names of the species found in each. This demands very much work, and in consequence we have only begun to learn the facts of distribution.

3. The animals of any region constitute its fauna; the plants are its flora.

4. Transition zones are areas lying between two life zones and containing some species from both zones.

5. There are more distinct life zones in the United States than in any other equal area of the world (unless in Australia). Some knowledge of these will add tremendously to the pleasure that one may find in travelling in this country. The most important zones are:

I. **Canadian Zone**: Northeastern U. S. and adjacent Canada; evergreen forests.

II. **Eastern Transition Zone**: New England to Ohio River and Missouri, boundaries poorly defined, a climate of extremes, deciduous forest, dense human population. Prairies in the northwestern portion. Covered with ice in the Great Ice Age, resulting in present mixture of northern and southern things in the area.

III. **Ozark Life Zone**: Southern Missouri, northern Arkansas, western Kentucky, etc.; deciduous forest; similar to Eastern Transition Zone.

IV. **Atlantic and Gulf Coastal Plains**: New Jersey to Florida and Texas; several life zones; forested swamp and salt-marsh, near the coast, rich fauna and flora; deciduous forest inland. Still poorly known biologically.

V. **Florida:** Low grass swamp, and pine and live oak forests; southern tip nearly tropic.

VI. **Mesquite Semi-Desert:** Southernmost Texas, poor brush cover of mesquite.

VII. **Great Plains:** Between hundredth meridian and Rocky Mountains; semi-arid, treeless except in river bottoms; cattle range; dry farming.

VIII. **Rocky Mountain Areas:** Idaho to northern Arizona and New Mexico; cut-up mountain and desert country, barren at lower elevations, evergreen forests at higher elevations, more arid in Northern Rockies. Black Hills of South Dakota an isolated range with distinct fauna and flora. Mountains of Utah also isolated and with a distinct fauna and flora; southwestern Utah related to California biologically.

IX. **Great Basin Deserts:** Oregon to northern Arizona; very arid, barren, alkaline, high plateaus in north, plants and animals few.

X. **Southwest:** West Texas to southeastern California; several types of deserts and life zones, broken up with well-forested mountains.

XI. **Sierran Zones:** Mountains on eastern boundary of California and in west-central Oregon and Washington; heavy coniferous forests; effective barriers to east and west distribution of life in North America.

XII. **Pacific Coast Zones:** California, western Oregon and Washington, extending to Alaska; several zones; parts of central and Southern California semi-arid, Coast Ranges and Vancouveran zones densely forested, with heavy rainfall.

DEFINE

Life zone
Fauna
Flora
Transition zone
Each of the life zones listed above

PROBLEMS

1. Do you think you have ever been in any other life zone than the one in which you are now living? If so, describe it.

2. Why are the life zones of the western third of the United States more sharply bounded, with narrower transition areas than in the eastern third of the country?

3. Why does the central third of the United States have the most poorly defined life zones?

4. From the maps in this chapter, figure out the approximate distance from your town to each of the three nearest life zones outside of the one in which you are living.

5. Find pictures in magazine articles or advertisements showing more than one kind of life zone. Bring them to class. Are the people, the houses, or the plants and animals shown in the pictures the most distinctive things of the regions?

6. Make a list including your state and ten or more of the near-by states. Under each state list the important life zones which enter into it.

7. Consider the history of the United States. What were the most important barriers that prevented Americans from spreading into every part of the country earlier than they actually did?

8. Which six of the American life zones seem to provide the best country for man to live in? List the advantages to be found in each zone.

9. Which of the American life zones were the last ones to be settled by Americans? In each case, name the reasons that prevented their earlier settlement.

10. List the advantages and the disadvantages of life in the life zone in which you are now living.

11. Which four of the American life zones should provide the most interesting scenery for the traveller to see?

12. If you had only two weeks for travel, and expense were no consideration, to which part of the country would you prefer to go? Explain your choice.

13. Many of the largest cities in the United States are located directly on boundaries between life zones. Using a geographic map and the life zone map in Figure 80, prepare a list of cities so located.

14. What reasons can you see for the location of a city on a boundary between life zones?

15. Make a list of fruits obtainable in your local markets but grown only in American life zones other than the one in which you live. From which life zone does each come?

16. Make a similar list of plant foods, other than fruits, which come to you from other American life zones.

17. Make a list of animal foods which come to you from other life zones.

18. Make a list of economically important plants, other than food plants, for which you depend on other American life zones.

19. Using the text in this chapter and any other reference books available, prepare a list of life zones, naming plants and animals which are characteristic of each zone.

20. Judging from the map in Figure 80, which of the American life zones would you expect to find continued into Mexico?

21. Similarly, which of the American life zones would you expect to find continued into Canada?

CHAPTER IX

MOUNTAIN-TOP BIOLOGY

There are few better places for observing the facts of distribution than in the mountain regions of our land. The most extreme climatic conditions, the most sharply defined life zones, and the most striking cases of discontinuous distribution are to be found there.

And since the western third of the United States is, generally speaking, mountain country, and since there are numerous mountain ranges of importance in the eastern parts of the United States, it is not impossible that many of you will some day have the opportunity to make observations on the plants and animals of mountainous regions.

Distribution Factors in Mountains

The chief factors in the distribution of mountain faunas and floras are climatic.

Altitude, as altitude, has little to do with it. If energy were all that was required, plants and animals could in time climb to any height. But the climatic conditions of higher altitudes are impassable barriers to most organisms, and they are the factors really responsible for the peculiar nature of mountain-top faunas and floras.

Winds become more severe at higher elevations, often blowing gales which sweep plants and animals to destruction. Many summits not high enough to be affected by low temperatures are barren because they are wind-swept. The effect of the wind markedly increases as one climbs, and the tall trees of the lower slopes become shorter and shorter until they are dwarfs not knee-high. The same specimens transplanted to the lowlands would grow into normally tall plants. On the lee side of a mountain, *i.e.*, on the side away from the prevailing winds, the plants and animals are not so much affected by "altitude."

Within the limits reached by mountains, the temperature of the air above the earth steadily decreases with increasing elevations. Winds at the heights are usually cold. Even then they cause rapid evaporation, and that results in a further lowering of temperature. Climbing a mountain is, therefore, the equivalent of travelling northward, as far as temperature changes are concerned. A rough average sometimes given is that each 1,000-foot rise in altitude is the equivalent of about 3° or about 200 miles northward change in latitude. There are, of course, many exceptions to this average.

Photo by Thos. H. Gill
Courtesy U. S. Forest Service

FIG. 90.—MOUNTAIN COUNTRY

While the barren summits of high mountains are ordinarily cold, and extremely cold at night, it should not be forgotten that they become surprisingly hot in the clear air beneath a mid-day sun. In this respect also they are like the Arctic regions, which experience extreme changes of temperature between the summer noon and winter night. Mountain tops and Arctic lands support only those organisms that can stand extreme temperature changes.

Winds from the lowlands have to drop their water in the form of rain as they become colder in passing over a mountain country, for the colder the air the less moisture it can hold.

The windward side of a range, therefore, may have a rainfall far in excess of that on the lee side, and the plants and animals that are found in the two places are often very distinct. An extreme case of such a difference is to be observed in the Sierras and Cascades of California, Oregon, and Washington.

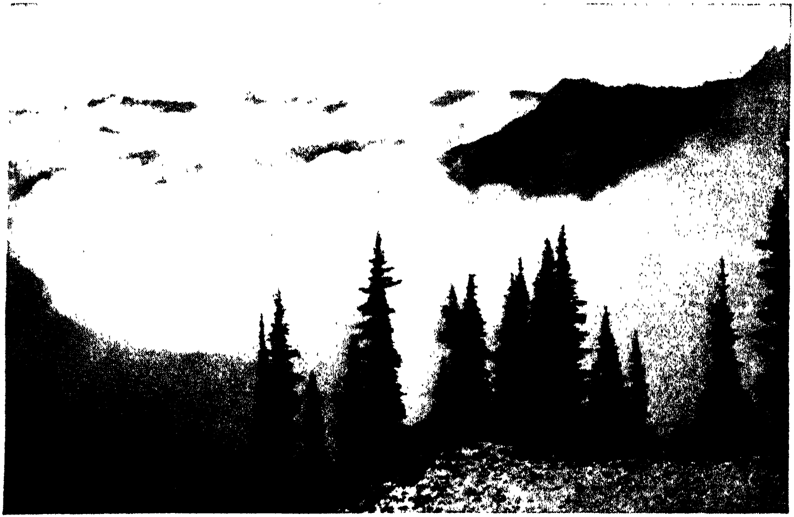


Photo by Asahel Curtis, Seattle

FIG. 91.—MISTS BATHING THE MOUNTAIN TOPS
View from Mt. Rainier, Washington State.

The westward sides of these ranges have a rainfall of 100 to 150 inches per year, and are consequently heavily forested; while the lee sides may have as little as five inches of rain, and are extremely barren. Even the casual observer sees that the two slopes belong to totally different life zones.

The increase in rainfall becomes very great at higher elevations. Contrary to what the uninitiated expect, there are often springs, bogs, lakes, and streams of water near the summits of high mountain peaks, and such places are often bathed in damp, drizzling fogs. The summits of lower peaks are, on the other hand, often very dry, for they are not high enough to force the clouds to drop their rain.

All the other factors of distribution, organic, geographic, food, soil, and geologic are, of course, as important on a mountain as elsewhere, but the climatic factors are the ones mostly responsible for the peculiar character of mountain faunas and floras.

Zones on Mountains

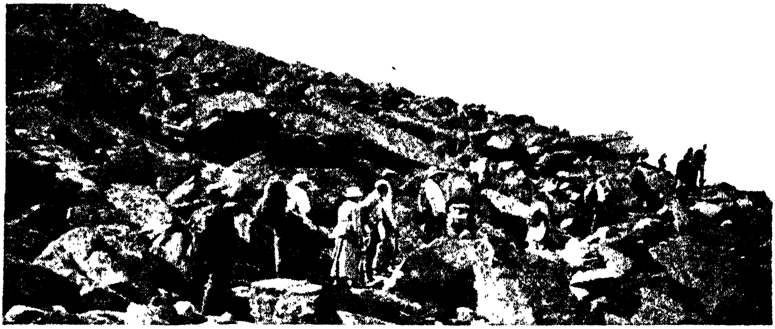
Because the climatic factors are so distinctly different at different elevations, several life zones may be found, one above the other, up the side of a single mountain. The boundaries of these zones are often rather sharply defined. You may see this from the accompanying illustrations.

As indicated above, the effect of climbing on a mountain is much the same as that of travelling northward on a level. The life zones that one crosses in going from the base to the summit of a mountain are likely to be those which are found as one travels from south to north on the level, with the zones arranged in each case in the same order.

New England Mountain Zones.—This arrangement of zones on a mountain is well illustrated on the Presidential Range of the White Mountains of New Hampshire, where a short climb of only three thousand feet (from 1,000 to 4,000 feet above sea level) takes one through four distinct zones. The valleys belong to the *eastern transition zone.* They support maple, beech, black oak, and white (gray) birch trees, cottontail rabbits, wood thrush, and meadow larks.

The slopes above this belong to the *Canadian zone,* having an evergreen forest, dark, damp, and dense with spruce and fir, the home of the northern jack rabbit and the nesting ground of the veery thrush, the hermit thrush, the winter wren, the junco, and an endless list of birds known southward only in migration.

The trees at the upper limits of the Canadian zone become stunted and dwarfed. They belong to the *Hudsonian zone.* Between the scattered patches of such growth one may find flowers and low shrubs of species that



Courtesy Shorey Studio, Gorham, N. H.

FIG. 92.—ARCTIC-ALPINE ZONE, WHITE MTS., N.H.

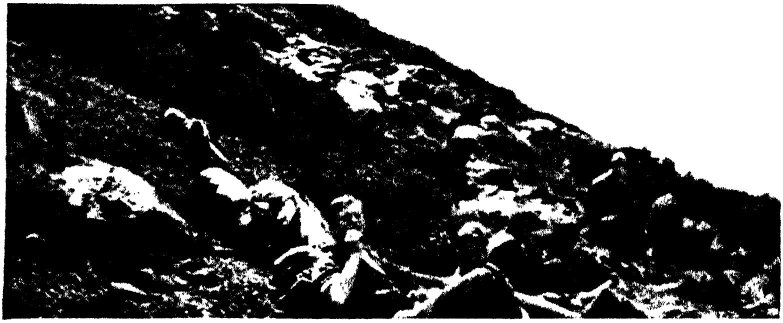
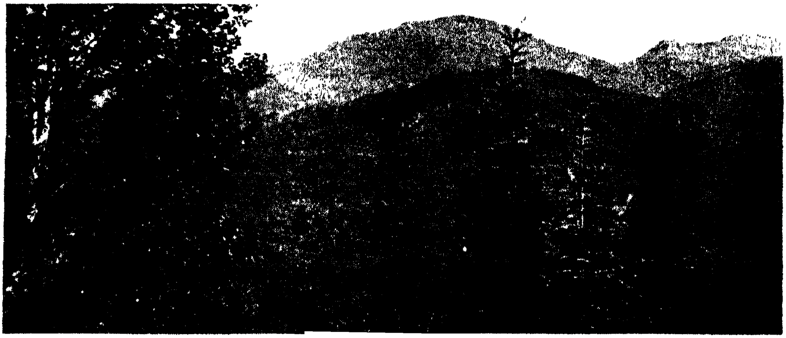


FIG. 93.—HUDSONIAN ZONE, WHITE MTS., N.H.



Courtesy Shorey Studio, Gorham, N. H.

FIG. 94.—CANADIAN ZONE, WHITE MTS., N.H.

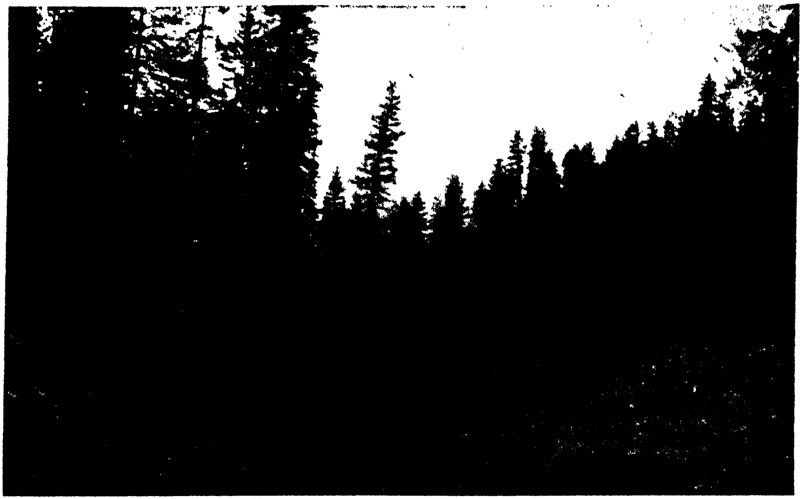
belong properly to Labrador and the region at the southern end of Hudson Bay.

At the upper limits of the Hudsonian zone, the scrub growth forms a tree line beyond which there are few plants more than a foot high. These, with the animal life of the region, belong to the *Arctic-Alpine* zone, for they are such species as are to be found in Greenland, Baffin Land, and the islands of the polar seas. We shall refer to this zone in a later section.

One may pass through these life zones, and see something of the plants and animals that occur in the country between Connecticut and Baffin Land, by climbing a few thousand feet in the mountains of northern New Hampshire!

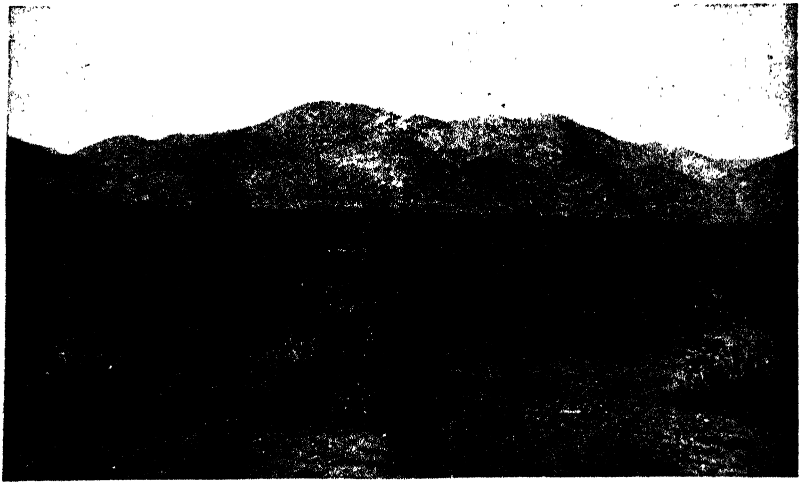
Southwestern Mountain Zones.—Even more striking are the life zones in the Southwest, that part of our country which includes West Texas, New Mexico, Arizona, and Southern California. Here the mountains rise abruptly out of the deserts. Their walls are usually steep, and often they are dry and barren. Looked at from below, they are forbidding rock formations. The towns of the Southwest are located in the deserts, the trails and the railroads stay to the more level lowlands, and few tourists who pass know anything more than the desert walls of the mountains.

Nevertheless, these ranges rise at higher elevations to zones of forested country, as I first learned in eastern New Mexico. While studying the gall wasps that occur on the oak trees of the region, I had travelled by railroad to a town located near a mountain range in which, foresters had assured me, there was an abundant oak flora. A native at the railroad station confirmed the information, so I set out across the wind-blown sand desert, to the base of the mountains. But as I climbed the cliffs, they proved as barren as the plain from which I had come. There were few plants besides cacti on the steep slopes. The heads of the canyons were dry, and harbored neither oaks nor bushes of any kind. Twenty-five hundred feet of climbing brought me within sight of the upper rim of the mountain wall, and no oaks had yet appeared.



Courtesy U. S. Biol. Surv.

FIG. 95.—FOREST ZONES IN THE MOUNTAINS HIGH ABOVE THE NEW MEXICAN DESERTS



Courtesy U. S. Biol. Surv.

FIG. 96.—THE NEW MEXICAN DESERT
The desert walls of the mountains are largely barren.

Discouraged, I went back to the town. In conversation with another native I learned that I would have found oaks if I had gone a bit farther. This seemed unreasonable, but I set out the next morning to climb the bare walls again, up, and on, to the very ledges at the top. And then, suddenly before me, there stretched a forested mountain country with dense, evergreen forests, with pines and with oak scrub beneath them, with running streams, icy brooks, and snow-capped summits. Here, above the heart of the New Mexico desert, apples grew as they would in Maine or in Oregon. It was no problem to understand that a boundary between life zones lay at the upper edge of the desert wall of those mountains.

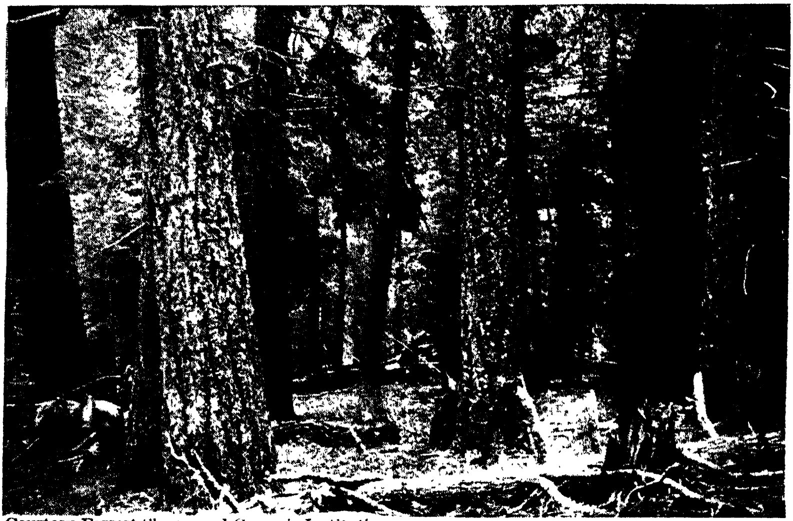
Many of the other ranges of the Southwest show as striking distributions of plants and animals. Some of them have slopes that are less steep, and on these there may be three or four zones between the deserts and the pine forests of the summits. The mountains that lie north of the Southwest more often rise from country which is forested, and one does not find so many different zones on them except where they, like the White Mountains previously mentioned, rise above tree level into an Arctic zone.

Arctic-Alpine Summits

Among the most interesting faunas and floras of the world are those that live on the Alpine summits, which are the barren areas above tree level on the higher mountains.

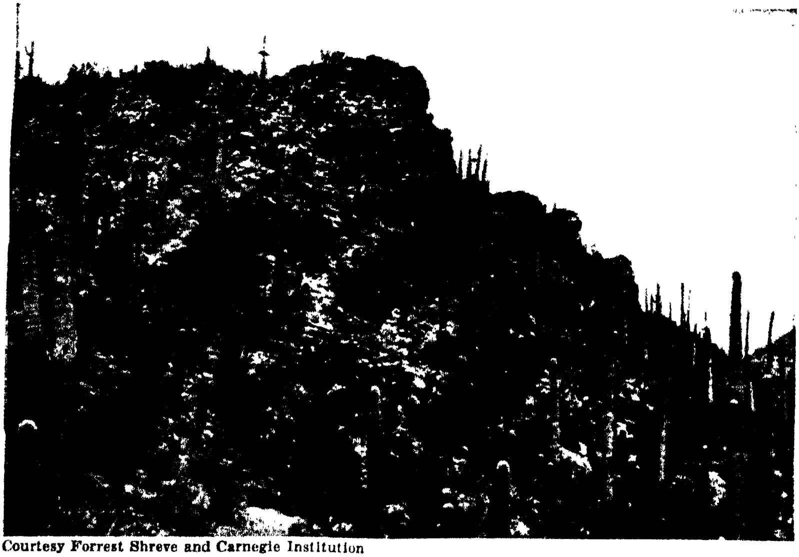
Now, it should be realized that some mountain tops are bare because they are so steep and so exposed to strong winds that they give no foothold to plants. Such wind-swept summits usually protrude abruptly above forests which do not reach a characteristically scrub growth at the higher elevations.

But there are other mountains whose summits are bare because they rise into climatic conditions resembling those of the northern parts of the continent. In such a case, the trees become dwarfed at the higher elevations, near the barren summits.



Courtesy Forrest Shreve and Carnegie Institution

FIG. 97.—SOUTHERN ARIZONA, AT 8,700 FEET
Forests of pine, fir, and Douglas spruce.



Courtesy Forrest Shreve and Carnegie Institution

FIG. 98.—SOUTHERN ARIZONA, AT 2,900 FEET

There are few experiences more unique than that of climbing through a tall forest, through scrub growth, and out above tree level. As the party hikes the trail in single file, the leader's head is the first to rise above the dwarfed trees, while further back along the column the forest still stands higher than a man. Soon the whole party reaches a low mat of twisted and gnarled growth. Nevertheless, many of the dwarf trees represent thirty or forty years of growth. Their dense and rugged branches make the way almost impassable. In a few yards more even this forest ends abruptly. Here is the beginning of the Arctic-Alpine zone.

Courtesy J. H. McFarland

FIG. 99.—ROCK PLANTS FROM ALPINE AREAS
Many plants grown in rock gardens are high mountain species from far ends of the world.

The height at which the tree line (or timber line) is to be found depends upon the latitude and upon the wind conditions. In the Andes of South America it is at an elevation of over 12,000 feet. On Pike's Peak it is over 11,000 feet. On Mt. Shasta in northern California it is 7,500 feet. In Washington

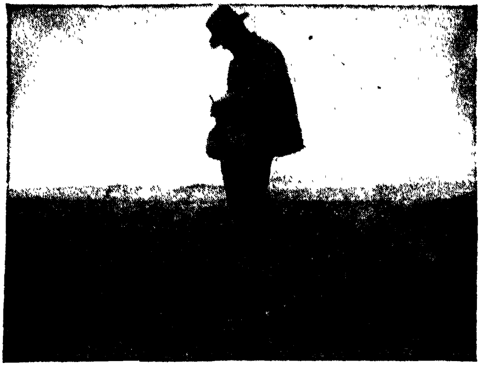


FIG. 100.—GULLIVER IN MOUNTAINLAND, AT 9,500 FEET

An alpine dwarf oak in the mountains of central Mexico.

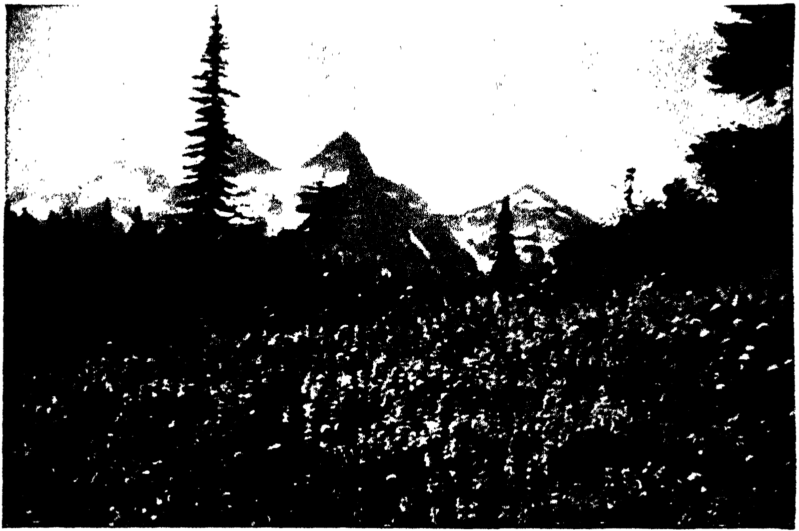
FIG. 101.—GULLIVER IN MOUNTAINLAND, AT 7,000 FEET

Black oak in the same Mexican mountains.

State it gets down to 6,000 feet. In northern New Hampshire it is as low as 4,000 feet in places on the Presidential Range. This last is the lowest tree level in the United States, due apparently to the unusually cold winds which sweep both sides of the New England mountains.

Truly Arctic-Alpine summits are most abundant in the Rockies, the Sierras, and the more northerly mountains of the Pacific Coast. East of the Rockies, the only Arctic - Alpine summits are in New York (Mt. Marcy), Vermont (Mt. Mansfield, Camel's Hump), New Hampshire (White Mountains), and Maine (Katadn). Although the Great Smokies of the Carolina-Tennessee boundary are even higher than are the White Mountains, they do not reach tree level because they are farther south.

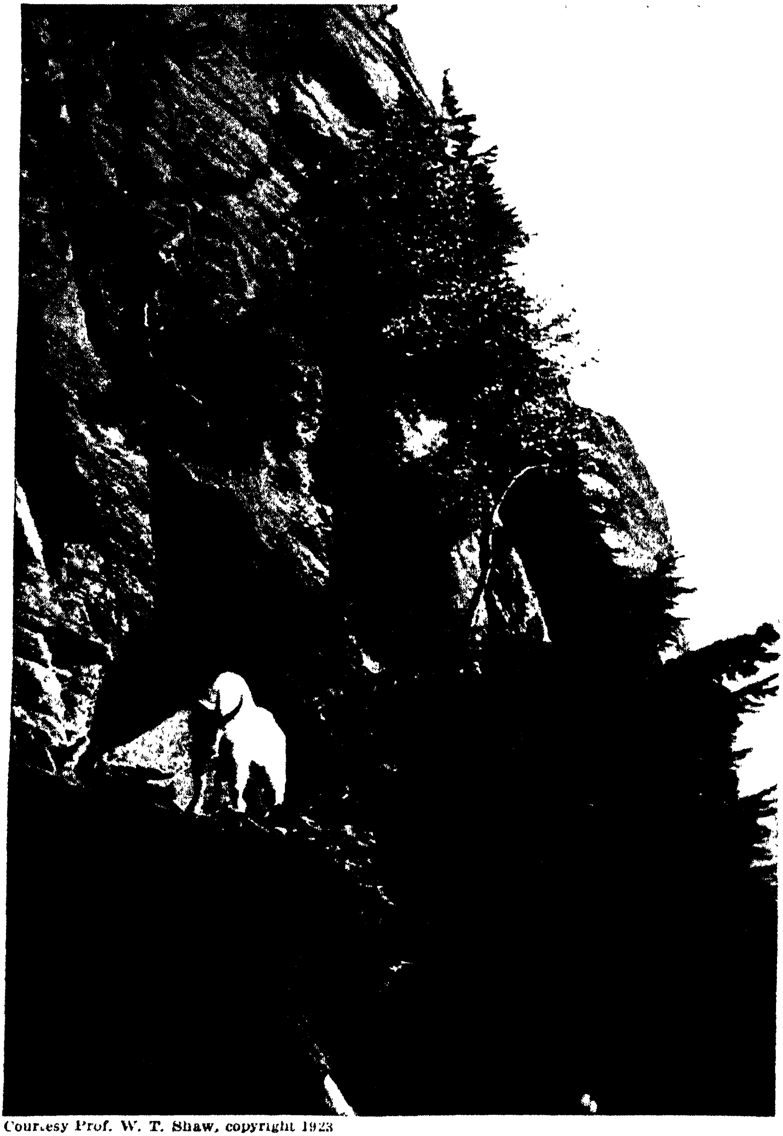
Arctic-Alpine Faunas and Floras.—The summits above tree level are barren, treeless, and wind-torn. The plants and animals are few, and they belong mostly to species found nowhere else in the world but on other high mountain peaks and in the far north in the Arctic zone of Labrador, Greenland, Alaska, and the islands of the Arctic seas. Some of the highest peaks in the western United States are even as permanently snow- and ice-capped as the far Arctic itself.



Courtesy A. L. Melander and Smithsonian Inst.

FIG. 102.—FLOWERS IN AN ARCTIC-ALPINE MEADOW
Washington State.

Tiny willow trees, not a foot high, hug tightly between the rocks, bearing their silken pussies in striking abundance. Similar mats of Arctic birches sometimes cluster under protecting ledges. The cranberries, the blueberries, and the bilberries of the mountains are species distinct from the similar things of the lowlands. Great clumps of Arctic sandworts



Courtesy Prof. W. T. Shaw, copyright 1923

FIG. 103.—THE MOUNTAIN GOAT

Found at the highest elevations in Washington and the adjacent Northwest, with near relatives in the Alps and the Himalayas.

(chickweeds), bearberries, baked-apple berries, and other northern plants display their brilliant flowers and fruits in the Arctic-Alpine springtime of July, quickly fading as autumn approaches in early August, and soon becoming buried in snow in the winter that sets in during September. Many of these plants grow in cold, acid bogs, or in meadows of incredible wetness.

Birds and mammals are few, for they are unable to find sufficient shelter and food. But sometimes a flock of white-plumaged buntings may be seen. The only abundant insects are weak fliers, for they are not hurt so much as stronger fliers would be hurt by the blowing winds. Grasshoppers, small butterflies, crickets, and beetles live in numbers beneath the rocks.

Origin of Alpine Faunas and Floras.—How these plants and animals first came to our mountains from their native northlands makes a story that begins with the Great Ice Sheets that formed and spread southward from the Arctics upward of a million years ago. In front of the slowly, very slowly advancing ice, Arctic conditions were introduced into remotely southern regions. Arctic organisms flourished in New Jersey and near Puget Sound, and even farther south in the mountains.

Courtesy Shorey Studio, Gorham, N. H.

FIG. 104.—"IF WE CLAMBER TO THE SUMMITS"

Then, after long centuries of these conditions, the ice sheet melted back to its location in the far North of today. Many northern plants and animals followed the retreating glacier, and those that stayed in the warming southlands were mostly exterminated. Some of them, however, retreated to the mountain tops, which were the last places to grow warm again, and even today the highest peaks have climates favorable for the persistence of the northern species. Here they remain, cut off from their relatives on other peaks and from their ancestral homes in the North by great stretches of warm lowlands which they cannot cross.

Along with the superb views, the wild winds, and the other things that belong to the mountains, you and I may find these Arctic things, if we clamber to the summits.

SUMMARY

1. Extreme climatic conditions are responsible for the sharply defined life zones of mountain country.
2. Winds become severe, temperatures become lowered (except for the high temperatures in the direct sun at noon), and the rainfall is greatly increased at higher elevations.
3. Several life zones may occur, one above the other, up the side of a single mountain. Each 1,000-foot rise in elevation has an effect on the plant and animal life of a 200-mile shift to the north in more level country.
4. In the White Mountains of New England, the zones are eastern transition, Canadian, Hudsonian, and Arctic-Alpine.
5. In the Southwest, cactus deserts give way to barren mountain slopes, and these rise through several zones of scrub growth to dense, evergreen forests on top. The highest peaks may rise to Arctic-Alpine zones.
6. Arctic-Alpine summits are those that rise to elevations where the climatic conditions resemble those of the true Arctics. They occur chiefly in the Rockies and Sierras, but also at one point in the Adirondacks of New York, in northern Vermont and New Hampshire, and on one peak in southeastern Maine.
7. The Arctic-Alpine fauna and flora is largely confined to these high mountain summits and to the northern Arctics. The only trees are low dwarfs; brilliant flowers bloom during July and August. The birds and insects are ground-inhabiting species, often poor fliers.

8. These Arctic species were brought south to the mountain areas during the Great Ice Age. They have persisted in the Arctic climates of these mountain summits while the neighboring lowlands have again become too warm for northern species.

DEFINE

Hudsonian zone
Tree line
Arctic-Alpine
Great Ice Age
Timber line

PROBLEMS

1. About how many miles are you from the nearest mountains that have Arctic-Alpine summits?

2. Have you ever climbed a mountain that had more than one life zone on it? Describe your experiences, or those of some friend who has climbed mountains, or some published account of mountain climbing.

3. Why do we refer to the areas above tree line as Arctic-Alpine, instead of Arctic?

4. Upon reaching the barren summit of a mountain, how could you tell whether the summit was bare because it was in an Arctic-Alpine zone, or bare merely because it was wind-swept?

5. What problems would one face in camping in the Arctic-Alpine zone of a mountain, which he would not have to face in camping at a lower, forested level on that mountain?

6. Why are there so few birds and mammals in the Arctic-Alpine zones of most mountains?

7. Many Alpine plants are now grown in rock gardens. Visit such a rock garden, or a nursery or greenhouse which has such plants. Report to the class whatever seemed of most interest to you in examining those plants.

8. Many Arctic-Alpine plants grow well enough in the summer at lower elevations and in more southern climates; but many of them *freeze to death* in the winter or spring in such new homes. Explain why this should be so.

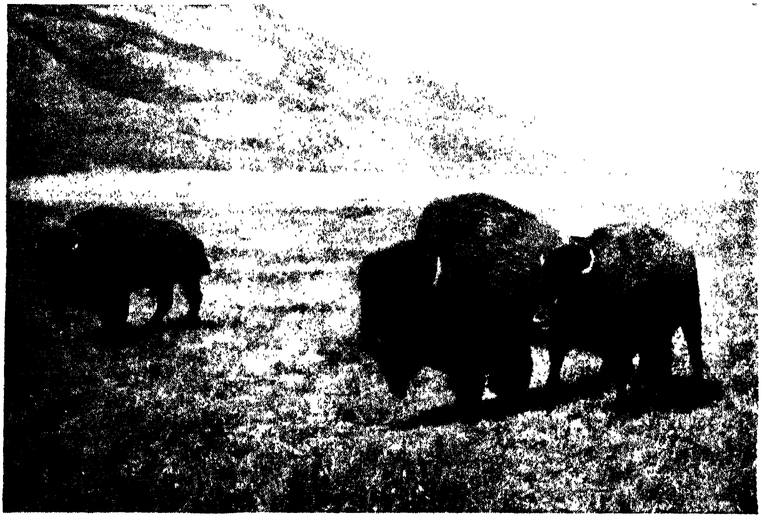
9. Find out how many miles you are from the nearest point reached by the ice sheets which were in North America during the Great Ice Age. A geology book will have maps that will help you.

10. In the western half of the United States, most of the larger cities are located on deserts or plains at the bases of mountains, but not in the mountains. Explain why. There is quite a list of factors involved.

CHAPTER X

REGIONS OF THE WORLD

The faunas and floras of North America, in spite of their differences, resemble each other more than they resemble the faunas and floras of most other parts of the world. That is what we should expect, considering that the broad oceans that bound the continent are impassable barriers for most land-inhabiting plants and animals. It is even certain that at one time the Central American land connection did not exist, and ocean separated the two Americas.



Courtesy Smithsonian Inst.

FIG. 105.—THE BISON

An animal found only in the North American region.

North America may be considered as a unit, a distinct *region,* as regards its plants and animals. There are, in all, eight or nine such regions in the world, each containing many life zones, but each rather distinctly different from any other region.

North American Region

Courtesy D. T. MacDougal and Carnegie Institution

FIG. 106.—BOTH NATIVE AMERICANS

By crushing the succulent pulp of the cactus, the Indian secures water to drink.

All of North America north of some point in Central America and south of the Arctics constitutes a single region.

If we were to journey out of North America, what familiar plants and animals would we leave behind? It seems difficult to realize that some of the very commonest of our species are peculiar to this continent. Yet that is true of the American porcupine, most of the genera of the mice, the raccoons, the mountain goats, and the prairie-dogs among the mammals. It is true of the turkeys, the turkey buzzards, the mocking-birds, the jays, the vireos—many, you see, of our common birds. Rattlesnakes are largely confined to North America, only one species occurring outside of this region in South America. Our black oaks and the redwoods of the Pacific Coast are confined today to America.

There are some groups, like the opossums, the skunks, the humming-birds, the wood warblers, the cacti, and the sunflowers that have representatives in both North and South America, but different species of these things occur on each continent. In Central America we find representatives of both the North and South American regions.

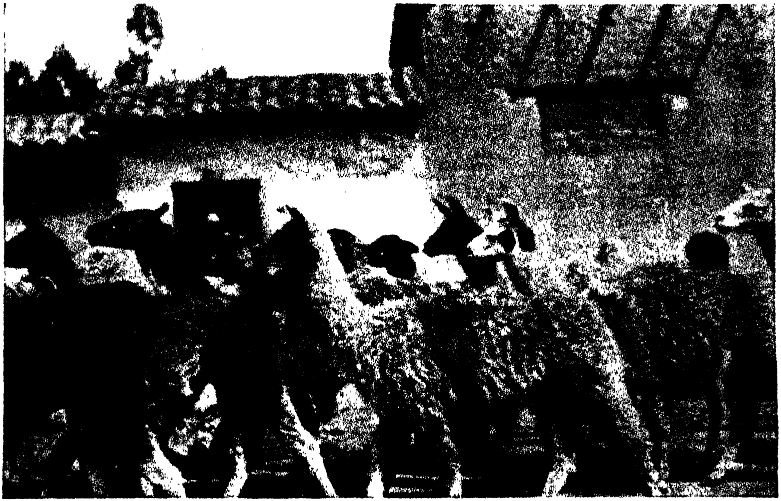
Courtesy W. R. Allen, Univ. of Ky.

FIG. 107.—A BIT OF JUNGLE IN THE AMAZON BASIN OF PERU

South American Region

South America is one of the most distinct regions of the world, being on a whole very different even from North America. The connection of the two continents has resulted in the northward migration of several groups of distinctly South American things, such as the armadillos, the opossums, and the humming-birds; but there are about four hundred kinds of humming-birds in South America in contrast to the very few species found in North America. There are many things, like the ant-eaters, sloths, guinea-pigs, chinchillas, llamas, New World apes, and mahoganies, that are wholly confined to the southern continent.

South America is a land of many kinds of country and of many life zones. Some areas are dry and barren, especially on the steep, western coast and at the far south of the continent, but much of the continent is tropic jungle and swamp land, belonging mostly to the great basin of the Amazon River. It is said that the intense abundance of species and of individuals in the South American tropics is matched in no other place in the world. On the other hand, the Andes, among the highest mountains of the world, rising abruptly on the Pacific Coast of the continent and extending for practically its whole length, have large areas that are dry, barren, rock-ridden, cold, and even perpetually snow-covered.



Courtesy W. R. Allen, Univ. of Ky.

FIG. 108.—THE LLAMA, A SOUTH AMERICAN RELATIVE OF THE CAMELS

Eurasian Region

The whole of Europe, with the whole of Asia north of the Himalaya mountains, and the northern coasts of Africa belong to the largest single region, the Eurasian. Although there are several life zones in it, there are remarkable uniformities over the great area of country that extends from England to Japan.

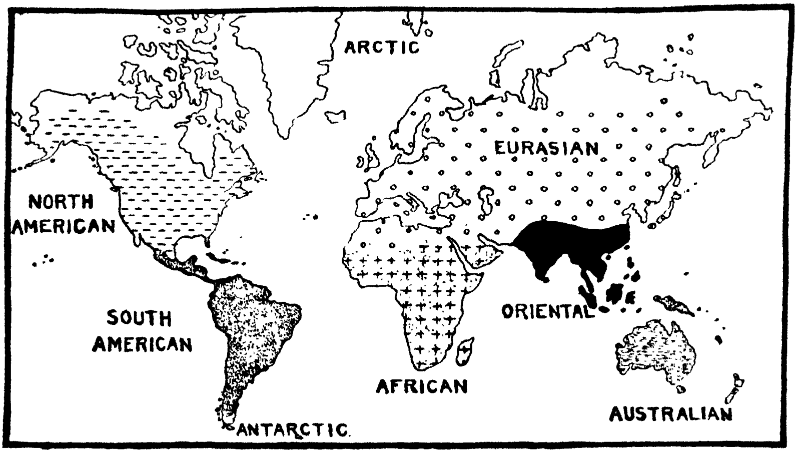


FIG. 109.—THE REGIONS OF THE WORLD

The plants and the animals of the Eurasian region more closely resemble those of North America than those of any other part of the world. Roses, honeysuckles, elders, dogwoods, white oaks, beech, chestnut, and many other genera are common to the two regions, although different species occur in each. Among the distinctive things of the Old World there are the European hedgehogs, the dormouse, the chamois, several peculiar moles and mice, many larks, the starlings, and several kinds of pheasants. But Eurasia and North America were connected, in the geologic past, both by way of Greenland and, more recently, by Alaska and Siberia, so many of the plants and animals of the two continents are closely related species.

African Region

The northern coasts of Africa, with some part of the barren, largely lifeless Sahara, belong to the Eurasian region which we have just considered. Only the more southern part of the African continent belongs to the African region.

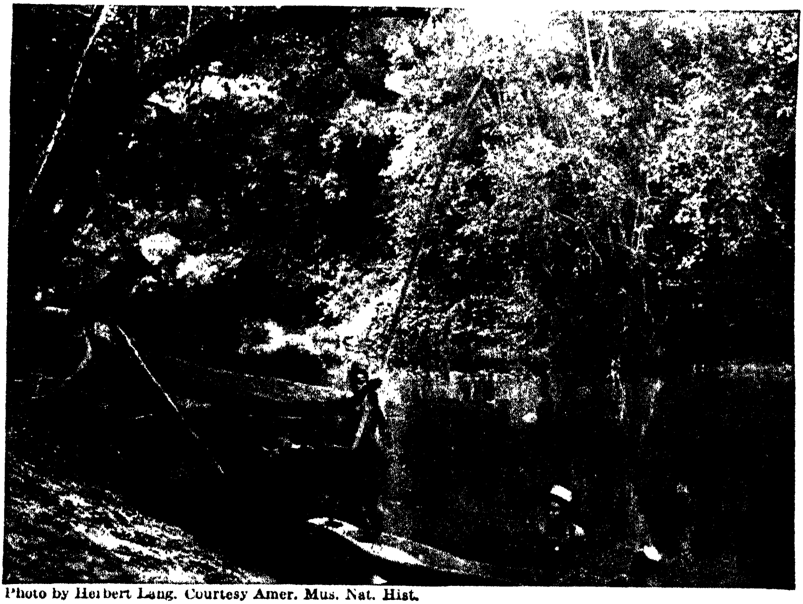


Photo by Herbert Lang. Courtesy Amer. Mus. Nat. Hist.

FIG. 110.—TROPIC AFRICA

Africa, again, is a land of variety, comprising many different life zones. The hot, moist, dense jungle country of the center of the continent is no more extensive than the more temperate forest and open grass country farther south. Scattered mountains of great height introduce other faunas and floras.

The African region is notable for including such large animals as the African elephant, the hippopotamus, the giraffe, the zebra, peculiar groups of antelopes, the gorillas, chimpanzees, and lions. There are no bears or deer.

The ostrich is one of the peculiar birds of the region. The oxpeckers feed on the ticks on the backs of the antelopes. The guinea hens come from this part of the world.

The island of **Madagascar**, lying southeast of the continent, is usually included in the African region, but its peculiar plants and animals might warrant us in thinking of this as another distinct region of the world.

Amer. Mus. Nat. Hist.

FIG. 111.—GIRAFFES AT A WATER HOLE, BRITISH EAST AFRICA

Oriental Region

Asia south of the Himalayas, meaning India, Indo-China, and the Malay Peninsula, constitutes the Oriental Region. All the other parts of the great continent belong to the Eurasian region. Yet, the southern country is so distinct that it gives color to most of our ideas of Asia as a whole.

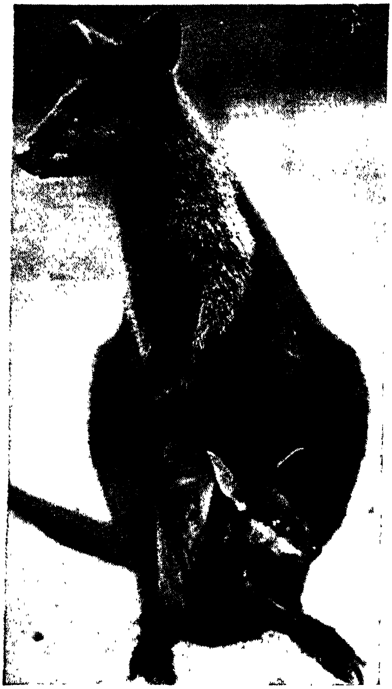
Largely tropic, in places densely forested, often with true jungles, this land also includes broad plains and high mountains. At the north the Himalayas, the highest peaks in the world, stand as unfailing sentinels between the Eurasian and Oriental regions, forever keeping their faunas and floras apart. The Indian elephant (larger than the African animal), the Bengal tiger, the orang-utan, the peacock, the bulbul, and teak wood are characteristic things whose names, perhaps, you have read in stories of India. Or you may have seen some of the animals in a zoological garden. The plants and animals of the Oriental region bear an evident relationship to those of Africa.

Australian Region

Stranded out in the midst of an ocean, the islands of Australia, New Zealand, Tasmania, and New Guinea show themselves more or less related biologically.

The area of Australia proper is almost equal to that of the United States. It contains tropic jungles, Alpine mountain summits, swamps, and deserts. Thus it offers habitats for varied faunas and floras. The interior of the great island is largely unexplored and reputed to be desert. Nearer the coast the forests are open stands of, mainly, eucalyptus trees, a number of species of which are now cultivated in California and elsewhere. The land is often swampy, or it may become swampy in the periodic flooding to which the country is liable. Off the northeastern coasts lie the great barrier reefs, the largest colonies of coral in the world.

"The land of living fossils" is the name fittingly applied to Australia because of the endlessly curious animals that live there. A few of the mammals, such as the wild dog dingo and the rats, show relations to the present-day things of other regions. On the other hand, most of the species, even whole orders, live today nowhere in the world but in Australia. Only fossils of similar things are found in other regions. Millions of years ago, primitive types of animals reached these islands, probably from the East Indies. Evolving in their own ways, they developed into forms that never could have survived if they had had to compete with the animals evolving on other continents. Protected by their isolation, the Australian species persist as living records of the past.



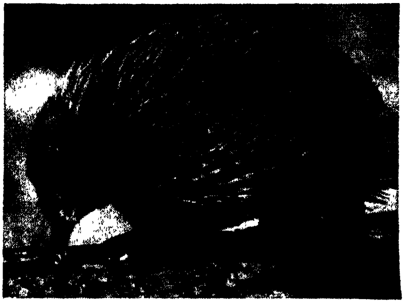
Courtesy N. Y. Zoological Society

FIG. 112.—AN AUSTRALIAN MARSUPIAL
Closely related to the kangaroo.

Chief among these curiosities are the *marsupials,* those mammals that carry their prematurely-born young in a nursery pouch for a considerable period after birth. The opossums of the Americas are among the very few living marsupials found outside of Australia, although fossils prove that the group was once more world-wide in its distribution. The Australian marsupials include the kangaroos (deer-like), the pouched wolf, the flying phalangers (resembling our flying squirrels), the wombat, and an endless number of other forms. There are even tiny pouched mice and moles.

Still more interesting are the duck-bill and echidna, representing the only mammals whose young come from eggs that develop outside the mother's body. The duck-bill lacks teeth, has broad, horny jaws and webbed feet, and lays eggs which resemble a primitive bird or reptile egg. Fossils of similar forms are considered to be connecting links between the mammals and the reptiles; but the living representatives of these connecting links are to be found in Australia.

The peculiar birds include the emu (ostrich-like), the birds of paradise of New Guinea, the extraordinary, giant moas of New Zealand (now exterminated), and the wingless kiwis of that latter island.



Courtesy N. Y. Zoological Society

FIG. 113.—AN AUSTRALIAN ECHIDNA

A mammal that lacks teeth and lays eggs.

Arctic Region

The frozen north is not entirely frozen, explorers tell us. The seas may be filled with bergs of ice or frozen on the surface, but the interiors of at least some of the land masses are bare for part of the year. These tundras become surprisingly warm in the summer suns. Winter, of course, brings low temperatures.

One of the hardest things for us to appreciate about the Arctics is the fact that the days are but short twilights for several months in the winter, while there is continuous day-and-night sunshine in the summer time. The organisms of the region must be equipped to withstand the winter extremes, and to take full advantage of the favorable conditions of the summer.

While the species of plants and animals are not particularly numerous, individuals, especially of the smaller, ocean-inhabiting organisms, are said to be as abundant as in the tropics and temperate regions. Moreover, plants, shrubby trees a few feet high, and a matting of bright-colored flowers may be found in places. Several large mammals, the polar bear,

Photo by Donald B. Macmillan. Courtesy Amer. Mus. Nat. Hist.

FIG. 114.—POLAR BEAR, NORTHWESTERN COAST OF GREENLAND

Courtesy Geol. Surv. Canada

FIG. 115.—JULY, WITHIN THE ARCTIC CIRCLE
A moth on the rock in the foreground.

Arctic fox, musk-ox, seals, and walrus, roam these regions. A number of birds, ducks, gulls, terns, plovers, and smaller species, nest here. Some of these animals are perpetually white, while others adopt white coverings in the winter.

Insects, particularly flies, midges, gnats, and mosquitoes, occur in such numbers in the summer season as to make it almost impossible for man and other large animals to stay in many places in the Arctics.

Copyright B. C. Murphy. Courtesy Amer. Mus. Nat. Hist.

FIG. 116.—PENGUINS IN THE ANTARCTICS

The seas teem with microscopic life, both plant and animal, and the fish that feed on these find an abundance of food. Seals feed on the fish and smaller marine life, and bears feed on seals and on fish.

Antarctic Region

The south polar might be expected to resemble the north polar faunas and floras. But that is hardly so. Although conditions in the two places are similar, there are great stretches of temperate and tropical oceans lying between them, and these prove absolute barriers to migrations of the larger organisms. There are few kinds of large mammals in the Antarctics, although seals occur in numbers.

It is, in contrast, a surprise to find that there are many identities among the microscopic forms of the two polar seas. It is possible that these travel across the tropics by going to the ocean depths that are very cold even at the equator.

The distinctive birds of the Antarctics are the penguins. These are large birds, some of them three feet tall. They live in great colonies and nest in the midst of the long winter nights when the temperature is fifty or sixty degrees below freezing.

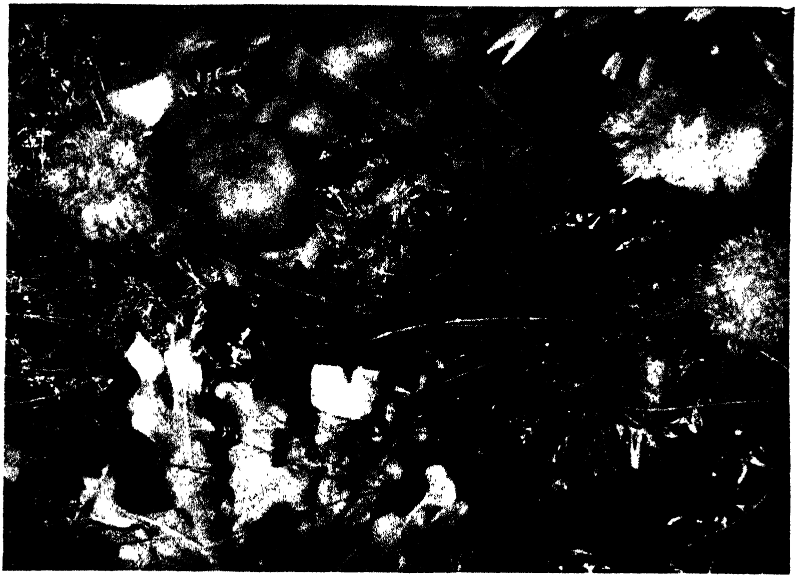
The Ocean Depths

The plants and the animals of the oceans have wider ranges, in general, than those of the land. This is because of the easy means of distribution afforded by open waters. Many of the fish of the ocean, and many of the seaweeds, are distributed around a considerable part of the world. The species that live on the coasts and on the surfaces of all the seas are in part cosmopolitan, and in part representative of the several regions that we have already considered.

Deep Seas.—But the deep seas have little to do with these other regions. They contain strange creatures that live under conditions as unique as can be imagined. Sunlight does not penetrate any great distance into the ocean waters, and so the creatures of the depths live in perpetual darkness. Plants are probably not found there. Some of the fish of the region flash lights from patches located on their sides or from other special structures, but they probably do no more to light up their abodes than a few fireflies do toward relieving the blackness of a night.

As peculiar as the darkness is the absence of sound in this region. The moan and the roar of the top of the ocean are locked to perpetual silence. Here the tides, the waves, the surge, and the fury of the ocean that we know are reduced to rest.

The pressure at the depths is tremendous. If you will recall that "a pint (of water) is a pound," you may realize what a weight rests on the bodies of deep-sea animals two or three miles below the surface. They do not feel this weight, for their own internal pressures are fitted for it, but when they are pulled to the surface they go to pieces, exploding as it were, because of the release from the pressure outside of their bodies.



Courtesy Amer Mus. Nat. Hist.

FIG. 117.—ALONG THE OCEAN COAST

Seaweeds, polyp animals, sea anemones, and many other forms are abundant.

The temperature of the depths is not much above freezing, and it stays so year in and year out without seasonal changes.

Numerous species of strange fish have been taken out of the deep seas. Polyps, sponges, starfish, and other types of lower animals are also known to occur. Some of the deep sea forms are colorless. All of these animals feed, probably, upon the dead organisms that settle down from the top of the ocean.

In spite of much recent work, we know very little of what goes on in the depths, because it is very difficult to dredge so deeply. As one biologist has put it, what we have learned by our deep-sea dredging is "about as much as we might learn of the land if a few balloons dragged nets over the surface of the country on dark nights."

Copyright Submarine Film Corporation. Courtesy R. W. Miner

FIG. 118.—EXPLORING THE TROPIC SEA BOTTOM

Don't you think that some knowledge of the distribution of the plants and animals of this world helps make it a more interesting place in which to live?

SUMMARY

There are nine biological regions of the world, as follows:

1. **North American:** North of Central America and south of the Arctics; black oaks, redwood, turkeys, bison, rattlesnakes, prairie-dogs —all confined to this region.

2. **South American:** Many kinds of country, tropics, plains, and high mountains; connection with North America is recent; ant-eaters, guinea-pigs, llamas, mahogany.

3. **Eurasian:** Europe, Asia north of the Himalayas, and north African coast; remarkably uniform; fauna and flora similar to those of North America.

4. **African:** Africa south of the Sahara, tropic jungle, open grass country, high mountains, large animals like African elephant, hippopotamus, giraffe, zebra, gorilla, lion, etc. Madagascar is nearly a distinct region.

5. **Oriental:** India, Indo-China, Malay Peninsula; tropic jungles, plains, and mountains, completely separated by Himalayas from Eurasian faunas and floras; Indian elephant, Bengal tiger, peacock, etc.

6. **Australian:** Australia, New Zealand, Tasmania, New Guinea; greatly varied country. The isolation of these islands is responsible for the fact that they possess the most peculiar plants and animals in the world. Eucalyptus, marsupials (kangaroo, opossum, wombat, etc.), duck-bill, echidna, emu.

7. **Arctic:** Winter twilights, with perpetual day in the summer; dwarf trees, bright flowers, large mammals (polar bear, musk-ox, seal, walrus), many birds; many flies, gnats, and mosquitoes as pests; oceans teem with life.

8 **Antarctics:** More barren of life than the Arctics; seals, penguins; the microscopic life of the oceans same as the Arctic life.

9. **Oceanic:** Coast and surface species sometimes cosmopolitan; deep seas without plants, with peculiar animals (fish, polyps, starfish, etc.) fitted for life in perpetual darkness, utter silence, tremendous water pressures, constant temperatures near freezing.

DEFINE

Region
Marsupial
The names of the nine regions

PROBLEMS

1. What are the two or three chief factors of distribution that fix the boundaries of each of the nine regions of the world?
2. What Eurasian plants or animals have you ever seen alive, in a circus, zoological garden, or elsewhere?
3. What African plants or animals have you ever seen alive?
4. What Oriental plants or animals have you ever seen alive?

5. Make a list of the wild animals of our circuses and the regions from which they come. Why would North American animals not do so well?

6. Explain in some detail why North American plants and animals resemble Eurasian species.

7. How far does the native distribution of the several races of men agree with the regions as we have bounded them? Can you explain the exceptions?

8. What are the differences between Eurasia as geographically defined, and the Eurasian Region of biologists?

9. Does all of South America belong to the South American Region? Explain.

10. Does all of North America belong to the North American Region? Explain.

11. Does all of Africa belong to the African Region? Explain.

12. If you were a deep-sea animal that could think, what would you consider the most peculiar features of the environment in which land animals live?

13. Find a map showing the Azores. The animals of the Azores are all close relatives of European species. How do you explain this?

14. On the other hand, many of the plants of the Azores show surprising similarities to those of South America and the West Indies. How would you explain that? Why this difference between the plants and the animals of these islands?

15. There are a number of plants in California which have their nearest relatives in China. How can you explain that?

16. There are more similarities between the native peoples of Mexico and the Chinese than there are between the Eastern American Indians and the Chinese. How would you explain that?

17. Make a list of plant foods which come to us from regions of the world other than the one in which we live.

18. Make a list of useful plants, other than food plants, which come to us from regions of the world other than the one in which we live.

19. Make a list of common weeds, harmful insects, or other pests which you know have come to America from Europe, Asia, or other regions of the world.

20. Do the faunas and floras of two regions differ more than those in two life zones? Carefully consider what you have learned about American life zones, and about the regions of the world.

21. Look up special references on the plants, animals, or human population of some region other than North America. Make a report to the class.

DISTRIBUTIONAL BIOLOGY: REVIEW

1. Review the definitions of all words listed at the ends of Chapters VII through X.
2. Review all of the summaries at the ends of those same chapters.
3. Review the problems given at the ends of those chapters.
4. Explain what is meant by each of the following statements. These are the important principles in that part of Distributional Biology which you have studied.

CHAPTER VII. **Geographic Distribution of Organisms.**—Each species is restricted to a limited range.

The range of each species is determined by organic, geographic, and climatic barriers and aids, and by the geologic history of the place in which it is found.

CHAPTER VIII. **Life Zones.**—An area which represents the common range of many of the species of a region is called a life zone. The boundaries of life zones are usually indefinite, sometimes with large transition areas between.

The United States presents a remarkable variety of life zones. In the observation of these the traveller may find a chief source of pleasure.

CHAPTER IX. **Mountain-Top Biology.**—Mountains provide clean-cut illustrations of life zones, due to the effects of wind, extremes of temperature, and increased rainfall at higher elevations.

The Arctic-Alpine areas on mountains extending above tree-line have species brought south from the Arctics during the Great Ice Age.

CHAPTER X. **Regions of the World.**—North America is only one of nine regions of the world, each with its own peculiar plants and animals.

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* Recommended as the best volume for the high school reference library.

UNIT III

Form and Structure

◆

The Biologic Science Called

MORPHOLOGY

◆

LIVING STRUCTURES
ANIMAL STRUCTURES
PLANT STRUCTURES
REPRODUCTION
EMBRYOLOGY

Preview

Biology never became a real science until biologists began studying morphology. Can you explain why?

Make a list of the professions or trades in which some knowledge of plant or animal morphology is of direct importance.

Is it possible to drive a car without knowing very much about the construction of the motor? Is it better to know something about it? Would a knowledge of the construction of your own bodies add to your efficiency or to your happiness in living?

Our enjoyment of the living world is materially increased if we have some knowledge of the way in which plants and animals are made. Can you explain why this is so?

Morphology, you see, is not a collection of dead facts and definitions intended for memorization. Morphology is, on the contrary, a very important aid to our understanding and enjoyment of the life of which we are a part and through which we are moving.

CHAPTER XI

LIVING STRUCTURES

Now we shall consider the structures of these plants and animals to which we have already been introduced.

Do you know how living things are built? Have you examined their parts, their smallest units? Do you know the perfection of their every structure?

Look at the man who is trained as a runner! Trim in build, easy in poise, abundant in his control, superb in his efforts at the goal! For beauty of form he has few equals. To see him in action is one of the thrilling things of the athletic field. But often as I watch the runner, I think of each inner structure of his body. Marvellous beyond human eye is the complicated perfection of his every muscle, delicate and sufficient are the intricacies of each nerve, and curious beyond conception the teamwork and the coördination of each other part.

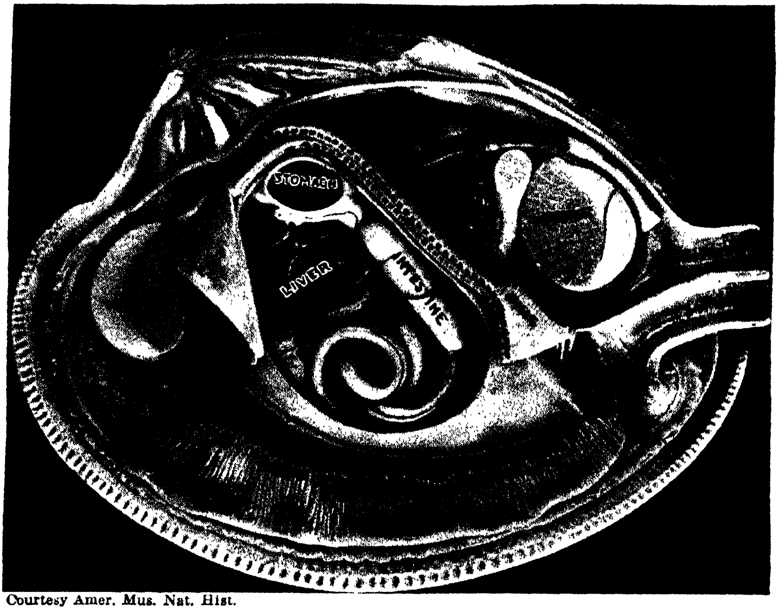
In order to understand how such an organism works we must know something about its form and structure, or what biologists call its *morphology*. We shall be able to consider only a bit of that science, but you may learn more of it if you take advanced courses in botany or zoology.

Organs

A living creature—a tree, an insect, a man, or any other organism—is not just a mass, a chunk of living stuff. That you must know if you have ever thought of the way your own body works. You know it is a collection of structures, each with its own particular function.

Living creatures are built somewhat like houses. Their parts, which we call their organs, tissues, and cells, are their bricks and their mortar, their joists and their beams, their steels and their concretes. Only of course living materials are much more interesting than the materials in a house.

The main parts of a living structure are its organs.[1] Ordinarily each organ or group of organs has a particular function. Your digestive organs handle the food you eat. Your heart and other circulatory organs distribute blood throughout your body. Your brain is concerned with sensations and thought, and controls all your other organs. In a plant the leaves, stems, and roots may be considered as the organs or groups of organs that do special work for the plant.



Courtesy Amer. Mus. Nat. Hist.

FIG. 119.—ORGANS IN A CLAM

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[1] Do not confuse the words *organ* and *organism*. An organism is any kind of living thing, plant, animal, or other sort. Each organism (unless it is a one-celled creature) is made up of organs.

Of course, while each organ has its functions, it is dependent upon the proper workings of all the other organs of the body in which it is located. You may know, for instance, what happens to the rest of your body when your digestive organs behave improperly.

The different groups of plants and animals have such different organs that no single description can possibly apply to all of them. For that reason, let us first consider the organs of the mammals—that group of animals of peculiar interest to us because it includes man.

Systems of Organs

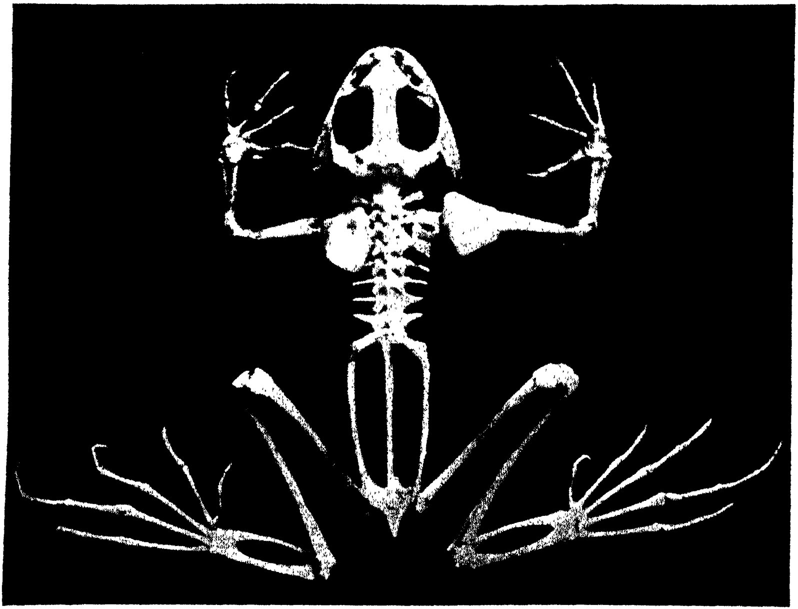
All of the organs of a higher animal may be considered as belonging to eight groups or systems of organs, called the integumentary, musculatory, skeletal, nervous, digestive, respiratory, circulatory, and urogenital systems.

Integumentary System.—The very outside of the vertebrate is its integument, consisting mostly of skin, but also including its nails, hair, feathers, or scales. The integument serves chiefly as a protection for an animal. In the mammals the sweat glands which are located in the integument help get rid of the waste materials of the body and help regulate its temperature.

Musculatory System.—This system makes up most of the flesh of an animal. The meat we buy at the butcher's is mostly muscle material. Living muscles are able to contract and elongate, and in that way they are responsible for most of the movements of an animal. One end of each muscle is attached to a bone, on which solid base the muscle pulls. Try to picture just what happens when you move the lower part of your arm, for instance. Plants do not have anything like muscles, and that is why they do not move as animals do.

Skeletal System.—In a vertebrate the skeletal system is made up of bones. In many of the lower animals the skeleton is closely connected with the integumentary system, and may consist of a limy shell (as with molluscs), a chitinized skin (as with arthropods), or some still different sort of shell (as with the starfish). In addition to providing the solid attachments for muscles, skeletal structures keep an animal's body in shape and so protect it.

Nervous System.—This is made of materials that are more sensitive than most other parts of the body. When you touch a stove, your skin or muscle does not feel the heat as much as the tiny nerves in your finger. Each nerve passes its sensations along to the central nervous system, which is the spinal cord (in the back-bone) and the brain. These perform somewhat the functions of a telephone switchboard, although they are constructed very differently. Each sensation that comes to them is stored or sent back along other nerves—for instance to the muscles of the burning finger—causing them to pull the



Courtesy Denoyer-Geppert Co., Chicago

FIG. 120.—SKELETON OF A FROG

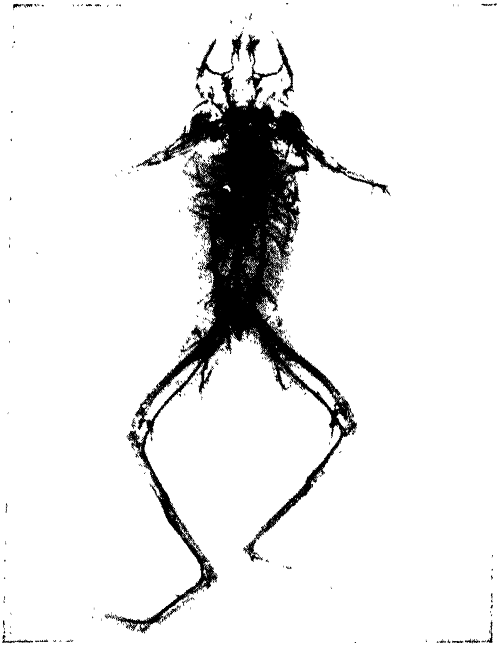
finger away. Nobody knows exactly how it is that a sensation can travel over a nerve. Nervous energy is as little understood as electric energy.

Sense Organs.—The eyes, ears, nose, taste, and touch organs are parts of the nervous system. They contain an especial abundance of nervous materials. They are located at the surface of an animal so they may discover what is going on in the world outside. Each sense organ is built for receiving a particular kind of stimulus. Thus the eye receives light and the ear receives sound. Most of the sense organs of an animal are in its head. Why is this so? If you will think of a creature that crawls, you may discover your own answer.

Digestive System.—In an animal the digestive organs are built to receive and to digest its food, and to get rid of the undigested materials. Connected with the digestive tract, throughout its length, there are glands, often of considerable size (the liver is such a gland). They furnish digestive juices.

Respiratory System.—This system includes the structures which are most used in bringing the oxygen of the air into contact with the other parts of the body. As you already know, without oxygen most organisms cannot live. In the higher animals the oxygen of the air, taken into the lungs, is passed through the thin walls of the lungs into the blood. Then the blood carries the oxygen to each of the other parts of the body. The gills of aquatic animals are similar to lungs, but are much more branched, and are more or less external structures so that considerable quantities of water may pass over them, oxygen being obtained from the water. Most insects have respiratory systems which are still different from those we have just described. The respiratory system also carries the waste gases away from the blood and throws them out of the body.

Circulatory System.—In vertebrates this system is filled with blood which carries the oxygen from the lungs and food from the digestive tract to all the other parts of the body, and carries away the wastes that the body produces. The circulatory organs of these higher animals consist of tubes which enclose the liquid blood. One of these tubes, the heart, is especially muscular, and by its contractions the blood is forced through the whole system, quite as the pumping station forces water through the pipes of a city. But the circulatory system is a circuit, with the blood returning to the station to be pumped over time and again. The tubes that lead away from the heart are the arteries, and inasmuch as they soon pass through the respiratory organs, they mostly carry purer blood. The vessels returning to the heart are called veins; naturally they do not pump (pulse) so strongly as the arteries; and since the blood in its journey has received waste materials from the other organs, most of the veins contain more impure blood. Very tiny, microscopic tubes, the capillaries, connect the arteries and the veins. Most of the absorption of oxygen from the air and of food materials from the digestive organs takes place through the thin walls of the capillaries. An insect has a very different type of circulatory system. We will describe the insect structures in the next chapter.

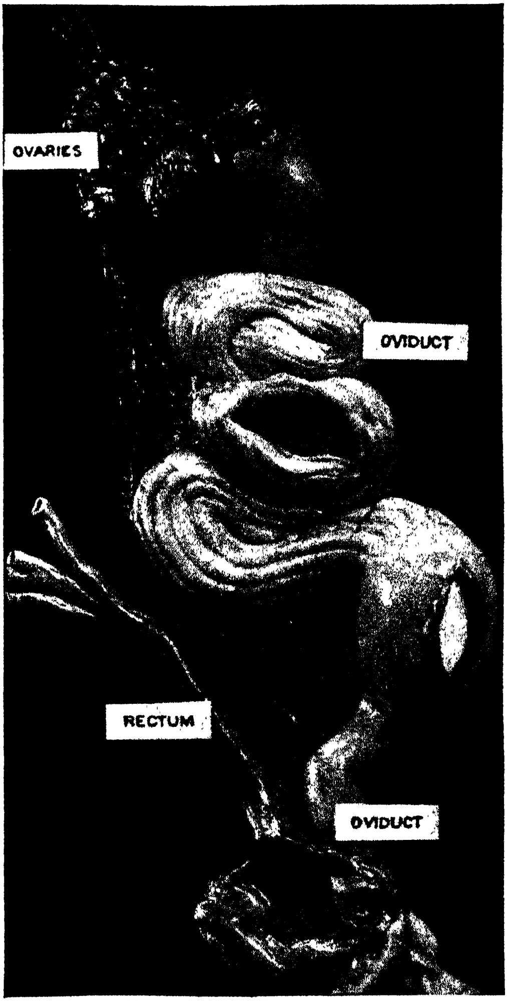


From G. G. Scott Biology. Crowell Co., Publ

FIG. 121.—CIRCULATORY SYSTEM OF THE FROG

An X-ray photograph.

Urogenital System.—This system has as its functions excretion and reproduction. The kidneys, which are parts of this system, are structures capable of taking waste materials from the blood. The liquid wastes are then passed along to the bladder, and finally excreted through the ureters. In the female animal, eggs are produced in the ovaries, another part of this same urogenital system. In the male, sperm (male reproductive cells) are produced in the testes. Reproductive cells, both eggs and sperm, are often spoken of as germ cells.



Courtesy Amer. Mus. Nat. Hist.

FIG. 122.—REPRODUCTIVE ORGANS OF THE HEN

Many of the lower animals lack special organ structures.

The organs of a plant, such as its leaves, stems, and roots, are in many ways very different from those of an animal, but are similarly parts of the organism which perform particular functions. Plant structures will be described in a later chapter.

Tissues

But still the beauty of a creature is not all disclosed by its organs, for organs are built of finer structures called tissues.

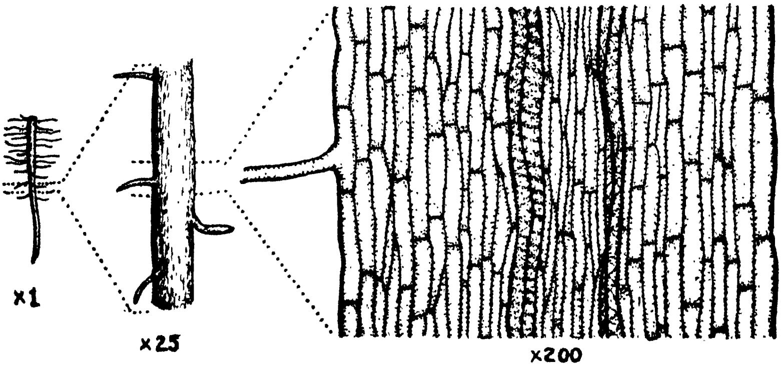


FIG. 123.—TISSUES ARE BUILT OF CELLS
Part of a root tip as it would appear if magnified.

Tissues are usually too fine to see unless we look sharply and dissect cleverly and employ the powers of a microscope. Think of the individual fibers of a piece of meat (muscle). They are bundles of the muscle tissues which build up the whole organ. Under a microscope one of the bundles would look as shown in the accompanying figure. Try to conceive what a complicated thing an organism would appear to be if we could see its whole tissue structure!

There are different kinds of tissue, bearing the names of the organs in which they are most abundant. Thus, in animals there is nervous tissue, muscle tissue, blood tissue, connective tissue, etc. Any single organ may (or may not) have more than one kind of tissue in it. Thus muscle organs are largely made of muscle tissue, but they also contain connective tissue and are closely related to blood vessels and nerves.

If you will try to imagine microscopic cells making up the whole of a large plant or animal, you will get some vague notion of the number of cells in such an organism. There are hundreds of millions of cells in the human brain alone—and of course no one can understand what that number means. The simpler plants and animals contain few cells, and you will recall that many of the thallus plants and all of the protozoa and bacteria have only single cells for each individual.

Cell Structure.—Most living cells consist of a *cell wall* containing a rather clear, colorless, jelly-like material known as *protoplasm.* The protoplasm is the really living part of the plant or animal. There is no other living material but protoplasm. In a later chapter we shall want to study this protoplasm in more detail.

Cells have a great variety of shapes. For convenience we often think of them as being spherical, ball-like; but most cells have very different shapes.

Courtesy C. G. Shaw

FIG. 127.—THE SUPERB ENERGY AND CONTROL OF THE RUNNER

But even finer is the perfection of those inner structures upon which his control depends.

We have said that a cell contains living protoplasm. If we examine that protoplasm very closely we find that it is never a perfectly clear jelly. Even a cell has finer structures within it. The protoplasm is divided into two parts, the *cytoplasm* and the *nucleus.* Both of them are protoplasm. The cytoplasm lies around the nucleus. Within the cytoplasm itself there may be bits of unabsorbed food materials and of wastes, and there may be numerous special structures, such as the bodies *(chloroplasts)* which contain the chlorophyll in plant cells.

Within the nucleus there are several structures, but only one of them, the *chromosomes,* will concern us here. These chromosomes are without color, and they cannot ordinarily be distinguished from the rest of the nucleus; but when a microscopic preparation of cells is colored with dye materials, the chromosomes stain more deeply than the rest, and are then plainly visible. Hence we have the name chromosome, meaning color body. Because chromosomes stain in a distinct way it is apparent that they are really different from the rest of the nucleus. Chromosomes, we shall see later, are the things that appear to control heredity.

What structures within structures these living bodies are! Perhaps now you will agree that the beauty of the living creature's form is surpassed by the beauty of its structure—that even the admirable form and control and action of the runner are out-marvelled by the finer structures of the organs and the tissues, the cells, and the still finer structures that allow him to win his race!

SUMMARY

1. All living organisms, except the one-celled creatures, are made up of organs. Each organ has a particular function to perform, but the happy functioning of any organ is dependent upon the proper working of all the other organs.
2. The organs of different groups of plants and animals differ greatly.
3. The organ systems of a vertebrate are:
    I. **Integumentary:** Provides protection.
    II. **Musculatory:** The means by which the animal moves.
    III. **Skeletal:** Provides the framework and attachments for muscles.
    IV. **Nervous:** The means by which the animal responds to heat, light, sound, etc. The sense organs are the external portions of the nervous system that receive heat, light, and other stimuli.
    V. **Digestive:** Receives and digests food.
    VI. **Respiratory:** Carries oxygen to blood and waste gases from blood.

VII. **Circulatory:** In vertebrates contains blood which carries oxygen and food to all parts of the body, and waste materials to lungs and to kidneys of the urogenital system.

VIII. **Urogenital System:** Takes liquid wastes from blood. Parts of system also concerned with reproduction.

4. Tissues are the masses of cells out of which the organs are built. Histology is the sub-science in which tissues are studied.

5. Cells are the smallest complete units of which all organisms are built.

6. Cells are usually microscopic, consisting of a cell wall containing a jelly-like protoplasm. The protoplasm is in part cytoplasm, and in part nucleus. Each of these kinds of protoplasm has several different materials within it.

7. The nucleus of a cell is its most important part, containing the chromosomes, the structures which control heredity.

DEFINE

Organ
Organism
Integument
Muscle
Skeleton
Nerve
Sense organ
Digestive organ
Liver
Respiratory organ
Circulatory organ
Heart
Arteries
Veins
Capillaries
Urogenital system
Kidney
Bladder
Ovaries
Testes
Tissue
Histology
Cytology
Yolk
Cell wall
Protoplasm
Cytoplasm
Nucleus
Chloroplast
Chromosome

PROBLEMS

1. Show how the musculatory system of a mammal depends upon the proper working of four other systems of organs.

2. Why do most animals have most of their sense organs in their heads?

3. What animals do you know that do not have all their sense organs in their heads?

4. What plant structures serve the functions of the mammal's integument? muscles? nerves? circulatory organs? skeleton?

5. How many functions has the mammalian circulatory system?

6. What organisms do you know that completely lack an integumentary system?

7. In which phyla of plants or animals are skeletal structures completely lacking?

8. In which phyla are musculatory structures lacking?

9. In which phyla are nerve structures present?

10. Which organisms lack a distinct set of digestive organs?

11. Which organisms lack tissues?

12. There is one group of organisms with cells distinctly simpler than the cells described in the present chapter. What is the group?

13. What advantages can you see to having organisms built of small cells, instead of being continuous living matter?

14. Is there a "division of labor" among the structures of an animal? Of a plant? Explain.

15. There are some kinds of algæ which consist of single cells that grow in great masses. How could one determine that this was a colony of single cells, and not a single individual consisting of many cells?

16. Modern biology did not begin its real development until the microscope was invented and fairly well developed. Can you explain why?

17. Eggs of many animals contain a great deal of fat. What advantage is there to the animal? Why do we so often eat animal eggs?

18. What kinds of commonly eaten meat are derived from these systems of organs: digestive, musculatory, skeletal, nervous, circulatory, respiratory?

CHAPTER XII

ANIMAL STRUCTURES[1]

While we have already considered how organisms in general are built, in this chapter we shall consider the structures of certain particular animals. In the next chapter we shall consider plant structures.

We shall begin our observations with an insect, for it is neither the simplest nor the most complicated of animals. After the study of the insect it will be possible to make ready comparisons with the simpler earthworm or the more complicated frog.

Grasshopper: External Structures

Any of our large grasshoppers, locusts, or katydids will make good material for studying morphology. Any other insect, a crayfish, or a lobster, will show similar structures, the grasshopper merely serving as an example of the whole great group of Arthropods.

If you can, you should go out and collect your own material. Watch it alive, out-of-doors, before you catch it.

Look over the outside, the external structures, of this animal. See the hardened skin. It contains a peculiar material called chitin. This external shell, as you will recall, is the only skeleton this creature possesses. Notice the three parts of the body, the head, the thorax, and the abdomen.

Head.—The head has two prominent eyes, but they are not single like those of a man. Each is made up of a hundred or more separate eyes; but just as you see only one landscape when you look out of a dozen small panes in one window, so the insect sees only one object when it looks through a compound eye. It cannot see more than a vague outline a few inches away, but if you will stop to figure it out, you will see that such a cluster works finely for detecting motion. The insect is not disturbed by seeing you, but it is disturbed by your movements. There may be (or may not be) three other, tiny, simple eyes in the middle of the forehead of the animal.

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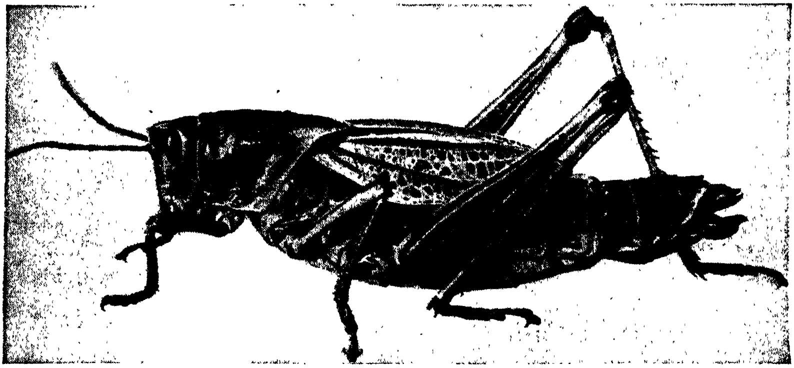
[1] Teaching Note.—This chapter will have little value unless it is accompanied by laboratory dissections performed by each student. The only instruments necessary are fine scissors, fine forceps, dissecting needles, and pans of water.



Courtesy U. S. Bur. Entomology

FIG. 128.—A GRASSHOPPER, SHOWING EXTERNAL STRUCTURES

Coming off from the front of the head are the two, thread-like "feelers" which we have called *antennæ*. Notice that they are jointed so they move very freely. Wiggling these antennæ constantly in front as it travels, the insect smells, and feels, and (in some species, not the grasshopper) hears with tiny sense organs located on the structures. In a very general way, these antennæ do parts of the work of human noses and fingers and ears.

At the lower front edge of the head, where the chin ought to be, you will see a confusion of mouth-parts. No two jaws for the grasshopper! A broad piece like an upper lip hangs over most of the parts. If you are clever you can dissect out these structures, and you will find jaws, and more feeler-like things, and organs that work like strainers and like fingers to push the food into the mouth. Haven't you watched living grasshoppers feed, perhaps as you were holding them between your fingers in order to see them "spit tobacco juice"? Feed a grass-blade to a live 'hopper and watch it use all that tangle of mouth-parts. Don't forget to feed the blade in sidewise, for that is the way insect jaws work. If a grasshopper could think (of course it can't), it would be very much astonished to see you holding your bread flatwise and using your jaws up and down!

Thorax.—The thorax is divided into three parts. This is more evident on the under surface. One pair of legs is attached to each of these three parts. The front wings are attached to the second part and the hind wings to the third part. The front wings are thick and stiff, and the grasshopper doesn't use them for flying, but for protection, and they hide the much larger, often brilliantly colored hind wings. One of the sounds which these insects make is produced by rubbing the front margins of the hind wings against the thickened veins in the front wings. The veins in an insect wing are merely thickenings, and have no relation to a circulatory system.

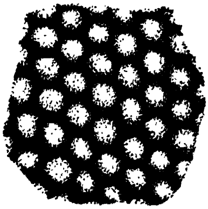


FIG. 129.—PART OF A COMPOUND EYE

Highly magnified.

The legs have many joints. The hind legs are much the largest. Why? Wouldn't an athlete, a jumper, delight in such legs? Notice the many spines on them; these give the push-off for the jump, just as a trackman's spiked shoes help him along.

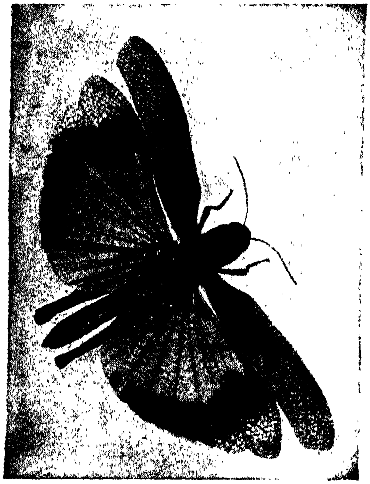
Internally the thorax contains a large part of the digestive tract and the large muscles connected with the wings and legs.

Abdomen.— The abdomen is divided into many segments. How many? At the very front end, just back of the attachment of the hind wing, there is a thin membrane looking like a drumhead. It is, however, not a sound-producing but a sound-receiving organ—in other words, an ear. Crickets and katydids have similar ears on the long, slender joints *(tibiæ)* of their front legs. Perhaps you are surprised that not all ears are worn human-style.

Down along the sides, very near their mid-line, you will find small spots like pin pricks. These are the breathing pores that let air into the branched tubes which make up the respiratory organs of the insect. Perhaps, again, you think this a queer place for an animal to wear such structures.

At the very tip of the abdomen are the external reproductive organs, rounded in the male, but in the female bearing four spreading tips that may force a hole in the ground where the eggs will be laid.

Internally, the abdomen contains the rest of the digestive tract, often considerable fat, and the reproductive organs.



Courtesy W. S. Blatchley

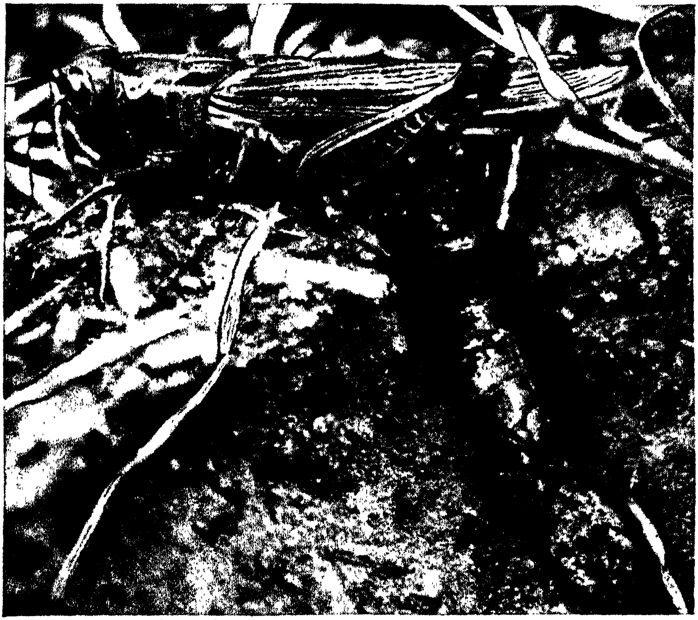
FIG. 130.—WINGS SPREAD FOR FLIGHT

Grasshopper: Internal Structures

Let us examine the internal organs of the grasshopper in the order in which they occur, from the upper *(dorsal)* down to the under *(ventral)* surface of the animal.

Rules for Dissection.—Start dissecting from the back. First take off the wings and legs. Then, using fine scissors, start at the hind end of the abdomen, push the tips of the instrument against the inside of the shell so they do not injure any of the internal organs, and cut along each side for the entire length of the body. Very carefully remove the shell from the back, using forceps or dissecting needles to scrape loose any of the internal organs.

In dissecting, you should never remove any structure until you are sure you know what it is, that you know all you wish to learn about it, and that it must be removed in order to see what is beneath. Use mostly forceps and needles; don't cut with scissors or scalpels unless it is necessary. Many delicate parts can be seen only when they are floated out in a dish or pan of water. If you keep these few things in mind, you should be able to make successful dissections of most of the animals whose structures you may wish to examine.



Courtesy U. S. Bur. Entomology

FIG. 131.—GRASSHOPPER LAYING EGGS

Circulatory System.—Lying directly on top of all the other organs, along the mid-line, often so close to the integument that you probably cannot help but remove it with the shell, is the only blood vessel an insect has. Most of the blood of this animal lies loose in the body cavity, directly surrounding the rest of the organs. The blood vessel is a delicate tube, with side valves so arranged that the blood can be drawn in from the body cavity, but it cannot get out of the valves. When the vessel pumps, the blood is therefore forced out at either the anterior or the posterior end of the tube. In this way all the rest of the blood in the body is stirred up and more or less moved about.

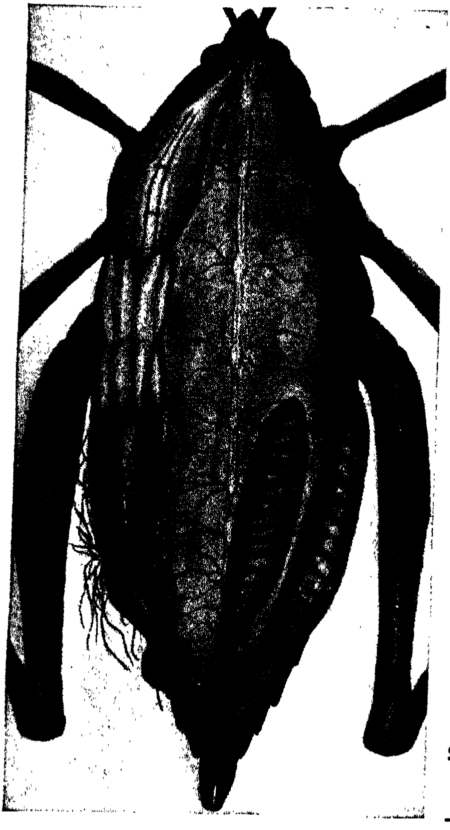


FIG. 132.—GRASSHOPPER DISSECTION

How many of the internal organs can you identify in this figure? The muscles and air tubes are not shown; the ovaries contain immature eggs.

Musculatory System.—No further dissection is necessary to see the insect's muscles. They have fibers like those in beef meat. The wing and leg muscles in the thorax are the largest. The muscles that move the abdomen extend lengthwise of the body (perhaps they too were attached to the shell you removed).

Reproductive System.—The reproductive organs are in the abdomen. A male will have *testes,* which are two, crumbly masses lying towards the sides. They are about a third as long as the whole abdomen. The female will have *ovaries,* which are similar to the testes if it is not egg-laying season; but if it is near that time, they will be enormous, thin-walled, fatty bags containing eggs, large enough to fill the greater part of the swollen abdomen. The eggs of a grasshopper become clustered in a thin-shelled package before they are laid.

Respiratory System.—By this time you will have noticed fine, stretchy threads resembling spider silk, occurring everywhere among the internal organs. Perhaps you can stretch one of them out to a length of several inches. These are not threads, but hollow air tubes which go to every part of the body. An insect does not have lungs, but the air tubes carry oxygen for respiration directly to every one of the organs of the body.

Digestive System.—The bulk of the internal organs of insects (unless the eggs are ripening) belongs to the digestive system. The narrow tube that leads in from the mouth is the *œsophagus*. This swells into the *crop*. Food in the crop can be *regurgitated*, meaning that it can be thrown back out of the mouth of the insect. Many of the social insects, like ants, bees, and wasps, regularly feed their young on such regurgitated food, and therefore the crop is sometimes called the social stomach. Inside, at the hind end of the crop, is a *valve*, and food that has once passed this valve cannot be regurgitated. The next portion of the digestive tract is the *ventriculus;* it has several glove-finger-like *glands*, attached at the anterior end. The remainder of the tract is intestine, with a mass of fine, thread-like glands attached near the end. The outside opening at the end of the tract is the *anus*.

Fat Body.—Distributed generally throughout the abdomen, and massing on either side beneath the digestive tract, there is a crumbly, fatty mass, the fat body. There food is stored, to be used during periods of starvation, and during the inactive pupal stage (in insects that have such stages).

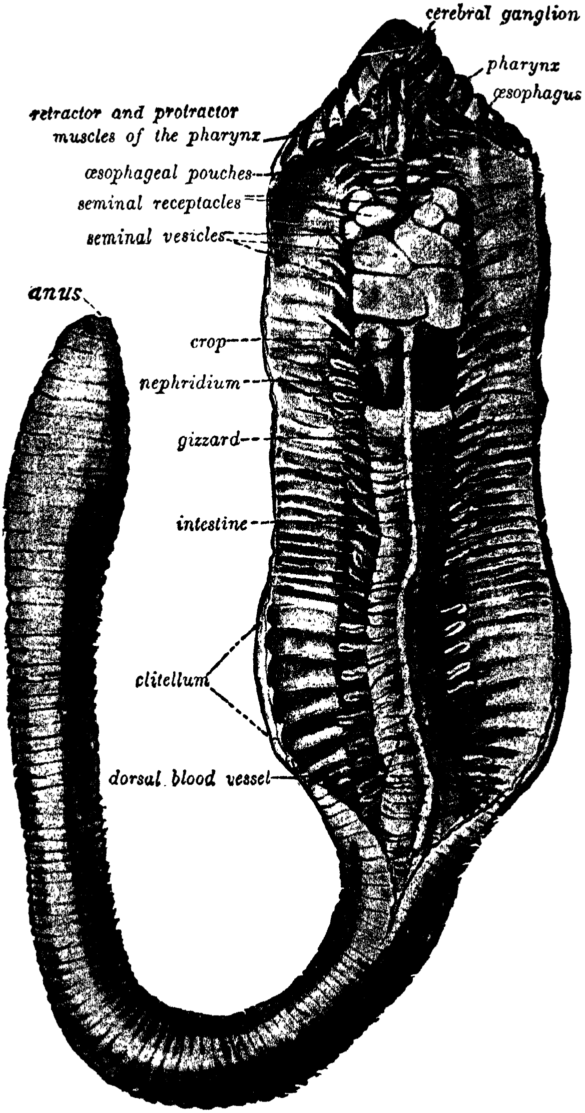
Nervous System.—The nervous system lies directly inside the shell of the under surface. It consists of a couple of rather colorless or whitish threads that lie on the mid-line, running the entire length of the body. These threads are connected with larger masses of nerve tissue to form a *ganglion* in each segment. From these ganglia finer nerves extend sidewise; these can best be seen in the thorax. The two largest ganglia are in the head; one lies back of the œsophagus; the other, a larger mass, is in front of the œsophagus, and can best be seen by cutting the shell off the front of the head and searching between and below the eyes. These head ganglia are the so-called brains of an insect, but they are not very much like the brains of a higher animal.

Earthworm Structure

Experiments with live earthworms are so interesting that you should try them even if they are not included as part of your laboratory work.

Living Earthworms.—Notice how the animal moves; try it out on moist, rough paper, and on moist glass. Place a worm on earth, and watching very carefully, try to discover how it manages to get into the soil. Experiment to see what differences there are in the methods used to get into loose and into packed soil. Try to discover what preferences the animal has for dry, for moist, or for very wet soils. Cover part of the box of worms, and try to discover what effect light has on them. Touch them with straws and needles, and see how delicate a touch they can feel. Jump on the floor, or jar the table: do the worms feel it? Bring a lighted match or an electric bulb near them: how are they affected by heat, and are you sure it is not the light that is disturbing them? If you wash the worm in water, the dorsal blood vessel can be seen through the skin, and the circulating blood is visible. Invent other experiments of your own.

Earthworms feed upon dead plant and animal materials, obtained mostly from the soil. They are found most abundantly, as every fisherman knows, in moist (not wet) and very rich soil which contains quantities of organic material. That is why they are to be found under manure heaps and in the



From Kellogg and Doane. Courtesy Henry Holt & Co.

FIG. 133.—DISSECTION OF AN EARTHWORM

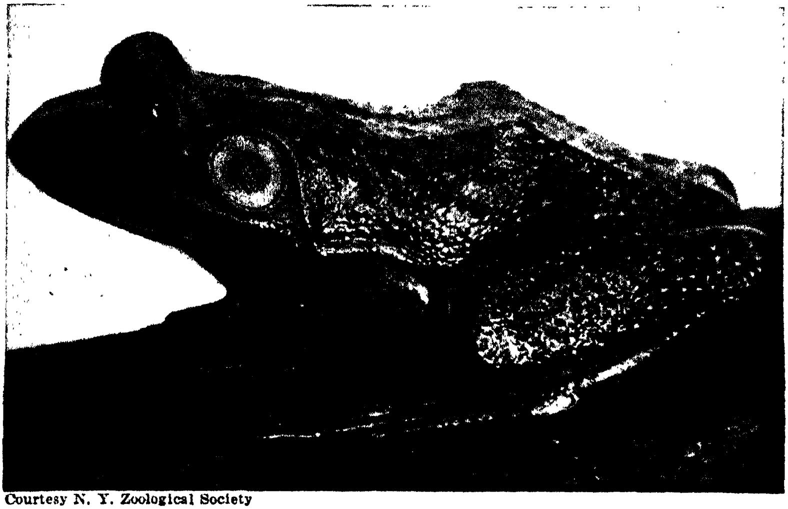
richest gardens and fields. In order to get its food, the worm may swallow quantities of earth, but only the organic matter is digestible, and the rest passes directly out of the body. These castings, left at night on the surface of the ground, may be brought from some depth. Darwin discovered that in some cases as much as 18 tons of earth is deposited on each acre by worms in a single year. This natural plowing is of considerable value in keeping our fields and gardens cultivated.

Externally the earthworm is different enough from an insect. What are the differences? Notice that there are no eyes. How then did the animal detect the light in your experiments? Rub your finger along the under surface of the body, and notice the four double rows of bristles which help the creature move, serving in much the same way that a telephone lineman's spikes catch into the pole he climbs. On a worm that is not too young, a third of the way back from the head, there will be found a swollen portion which produces a capsule that holds the eggs while they are beginning to develop.

Internally the worm has very much the same plan of structure as an insect. Describe the similarities and the differences. Notice that cross-wise partitions divide the body cavity into almost as many parts as there are segments. The blood is contained in a closed circulatory system, with both a dorsal and a ventral vessel, and with connections. The pumping of the blood is done by all of the larger vessels, especially those near the head. The reproductive glands are nearer the head, in the swollen part of the body. There are no special respiratory organs at all, oxygen being absorbed directly through the skin. The digestive tract is mostly a straight tube, without as distinct subdivisions as those found in the insect. There is no fat body. But although the insect lacked special excretory organs, the worm has two small kidneys in (almost) every one of the segments; these kidneys are to be found inside the ventral wall. The nervous system is very much like that of the insect.

Frog Structures

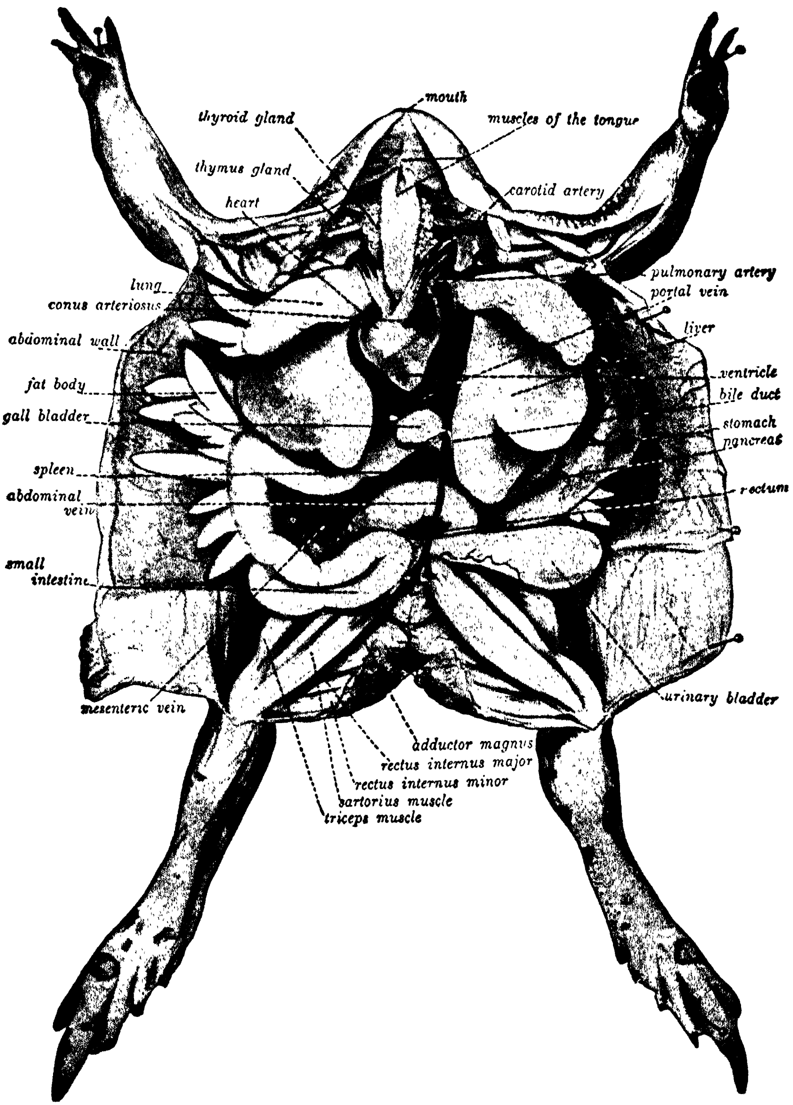
The living frog is very interesting to watch. Notice the motions of the throat during breathing. Amphibia must be kept moist or they become unable to take oxygen through their skins, and in consequence they die. The circulation of the blood may be observed with a microscope directly through the skin of the web of the foot. The method in which the tongue is used to capture insects and other food is so unique that a long time might profitably be spent in trying to observe it. Put live frogs on differently colored backgrounds and see how much they will change color.



Courtesy N. Y. Zoological Society

FIG. 134.—THE LIVING FROG

The external structure of a frog is probably more or less familiar to you. There is a head and a trunk with limbs. Examine the eye and its *three* eyelids carefully. The drum of the ear is on a level with the skin, the outer ear of the higher



From Kellogg and Doane. Courtesy Henry Holt & Co.

FIG. 135.—DISSECTION OF A TOAD
Similar to the frog in structure.

vertebrates being lacking. Examine the interior of the mouth. Compare the limbs of the frog with those of the human, and see that there are no finger or toe nails.

Internal Structure.—The frog is a fairly typical vertebrate, and as such shows many differences from the insect. The main blood vessels and the main nerves (the spinal cord) have just the reverse positions in the two animals; that is, in the frog the spinal cord is dorsal and the main arteries ventral. Consequently it will be best to begin dissection from the ventral surface. The vertebrates have very extensive, internal, bony skeletons, and you should examine the skeleton as you work. Possibly you will need an additional specimen which you will dissect only for the bones.

Compared with the insect, the internal structure of the frog is most different in the following respects: The muscles form a solid layer beneath and attached to the skin, and in places, particularly in connection with the limbs, form solid masses of meat material. Practically all of the internal organs are in one large cavity in the trunk. They are held in place by thin, transparent membranes which will need to be cut in dissection.

The digestive system has an œsophagus, stomach, small intestine, large intestine, and a hindermost cavity, the cloaca. The gall bladder is connected with the intestine. A flesh-colored digestive gland, the pancreas, lies in the U-shaped loop between the stomach and the intestine. A purplish gland, the spleen, lies in the thin membrane near the front end of the large intestine, and is closely connected with the circulatory system. One of the largest organs in the body, the liver, is a three-divided mass, another gland which manufactures digestive fluids.

The blood is entirely confined to an elaborate system of blood vessels, and is pumped by an especially muscular organ, the heart, which is about in the mid-line (not on one side). Examine the internal structure of the heart, with its three cavities.

The respiratory system consists of two bag-like structures, the lungs. Blow these up with a straw or blowpipe.

There is a well-developed excretory system with two rather solid kidneys against the wall of the lower part of the back, and a large, thin-walled sac, the bladder, which opens through ducts into the cloaca. The ovaries or testes will be found near the kidneys, with much-coiled ducts opening also into the cloaca.

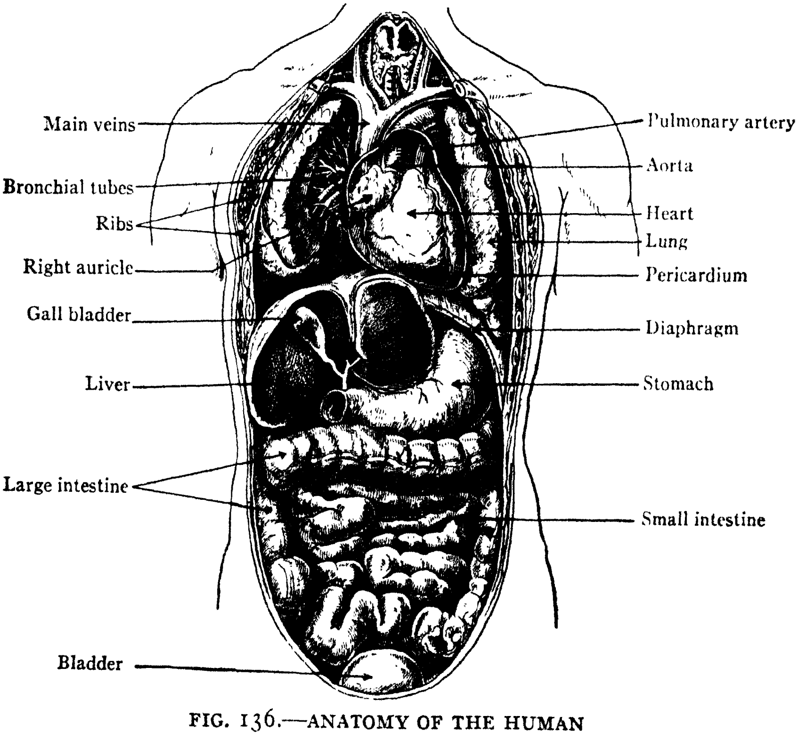


FIG. 136.—ANATOMY OF THE HUMAN

How many of the structures can you identify when the labels are covered?

Most of the nerves are too delicate to be easily dissected, but the cord in the spine and the brain may be examined if care is taken in cutting their bony coverings.

Human Structures

The frog is typical enough of other vertebrates to give a good idea of the internal plan of the human structure. Nevertheless there are many differences, a few of the most important of which should be kept in mind.

First of all, the human trunk contains two cavities (instead of the single one of the frog) which are separated by a diaphragm (at the lower part of the chest). In the *chest cavity* are the lungs, the heart, and the œsophagus. All of the other organs lie in the *abdominal cavity,* the stomach and liver being at the top, and most of the cavity being occupied with the very long (20 feet or more), very much coiled, small intestine. The heart has four cavities instead of the three of the frog.

SUMMARY

1. To obtain a further knowledge of the structures of living organisms, we must examine the structures of a few typical kinds of plants and animals in more detail.

2. We begin with the grasshopper not only because it is easily obtainable, but also because its organs are distinct and easy to observe, neither too simple nor too complicated to understand.

3. The grasshopper external structures which are typical of many other insects are its external skeleton, division of the body into head (bearing compound eyes, antennæ, and mouth-parts), thorax (bearing two pairs of wings and six legs), and abdomen (note breathing pores and external reproductive organs).

4. The grasshopper internal structures include a dorsal blood vessel, a ventral nervous system (with nerve cord and ganglia), three main sets of muscles, reproductive organs, respiratory organs, a digestive system divided into six or more parts, and a fat body. If you have made an actual dissection of the insect you should be able to describe each of these structures.

5. Live earthworms make interesting material to observe and experiment with in the laboratory. They are of some economic importance as cultivators of soil.

6. Externally the lack of eyes, the walking bristles, and the reproductive capsule are prominent structures of the earthworm.

7. Internally the worm has the body cavity divided by cross partitions, a closed circulatory system with well-developed blood vessels, no special respiratory system, a simple digestive tract, and numerous kidneys.

8. The frog has an internal skeleton of bones, one large body cavity, a much-divided digestive system, a closed circulatory system, and specialized respiratory and excretory systems.

9. The human structure differs markedly from that of a frog in having the body cavity divided into a chest and an abdominal cavity, and in having a four-chambered heart.

DEFINE

Thorax
Compound eye
Dorsal
Ventral
Œsophagus
Crop
Regurgitate
Ventriculus
Fat body
Ganglion
Trunk
Gall bladder
Pancreas
Spleen
Diaphragm

PROBLEMS

1. In what order would you find the internal organs of a grasshopper if you started on the ventral and dissected to the dorsal surface?

2. In what order would you find the internal structures of a frog if you started on the dorsal and dissected to the ventral surface?

3. Which organ systems of the grasshopper differ most from those of the vertebrate: the circulatory, respiratory, digestive, nervous, or skeletal? Explain.

4. What are the advantages and disadvantages of the insect skeletal system compared with the vertebrate skeletal system?

5. To what part of an insect's body would you apply gasoline if you wanted to smother and kill the animal?

6. What insect organs perform the functions of vertebrate blood?

7. What were the outstanding differences in internal structure between the grasshopper and the earthworm?

8. If possible, dissect a cockroach and prepare a table listing the structures that are different from those of the grasshopper, showing how these structures differ in the two insects.

9. Explain the difference in meaning between a closed and an open circulatory system.

10. Examine the figures in this chapter showing the internal structure of the grasshopper, earthworm, frog, and human. Cover the labels so you cannot read them, and see how many of the structures you can name.

11. Name the parts of the insect digestive tract in order, beginning at the hind end of the tract.

12. Considering both the frog and the human, what internal structures would you name as distinguishing vertebrates from all other animals?

13. What are the most important differences between the internal structures of the frog and those of the human?

14. Which parts of a grasshopper perform the same functions as the human nose?

15. What structures of an earthworm are of particular advantage to it in its life underground, in the soil?

16. Is an earthworm so constructed in order that it may live in the soil? Or does it live in the soil because it is constructed as it is?

17. Which of the external structures of an insect are segmented? Of an earthworm? Of man?

18. Which of the internal organs of an insect are segmented? Of an earthworm? Of man?

19. There are two main plans of animal structure: bilateral, in which structures are paired on either side of a mid-line; and radial, in which structures are arranged like the spokes of a wheel. Which phyla of animals have their organs arranged bilaterally, and which radially? Which are neither bilateral nor radial?

20. Name some organs in man which are not bilateral. Be careful in your answer!

21. Now make a list of the occupations, trades, or professions in which a knowledge of animal structures would be of practical, dollars-and-cents importance.

CHAPTER XIII

PLANT STRUCTURES[1]

The great tree is a live thing. But it seems so different from an animal! How does it eat? How does it breathe? How does it reproduce? What structure has it for doing such things?

Let us see!

Leaves

The leaves of a plant are able to respire, to manufacture food, to aid in the circulation of water and of food, and to digest food. It is apparent that they are very important parts of a plant, and that their structures must be fit for such duties.

Leaves are green, except in parasitic plants. Their green material, *chlorophyll,* occurs in small packets (chloroplasts) widely distributed in the leaf. It traps the sunlight, and in some way or other helps manufacture sugars, which are the foods of the plant. This ability of plants to manufacture their own food is a very remarkable one, and later we shall want to learn more about it.

A leaf is flat. Well, now, what advantage is there in having it flat? Have you ever stopped to question that? One of the old English philosophers said that it takes a "mind debauched by learning" to ask simple questions; but I hope you will learn to ask about even the commonest things. Then you may find that the leaf manufactures its food more efficiently because it is flat. The process occurs only in cells that are reached by sunlight. Were the cells too many layers deep the light could never enter; hence the efficiency in having them spread thin!

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[1] TEACHING NOTE.—This chapter contains more material than its length would suggest. It should be spread over several lessons. The long list of problems at the end of the chapter will provide material for additional lessons.

Leaves are scattered over stems and in consequence sunlight may reach each of them. If they are not in satisfactory positions, they move themselves as far as they can. Looking at a stem directly from above, one can often see something of every leaf of the plant, forming what is called a leaf-mosaic. If such a mosaic is not found, it means that the leaves shift their positions enough in a day to secure the necessary light. Shut off from the sunlight, the lower branches of a dense forest of trees become leafless and dead, starved because they cannot keep their food factories running.

Stomata.—The upper and under surfaces of leaves are covered with very thin tissue that contains no chlorophyll. This is the *epidermis*. You have separated it from the rest of the leaf when you made "blow bags" from the plant called live-forever or frog plant. The epidermis protects the other structures from injury and from too rapid temperature changes. It is practically a water-proof covering, shielding the inner tissues from rains and dews, and keeping the water in the leaf from being evaporated too rapidly. Normally the epidermis on the top of the leaf is solid and unbroken. The lower epidermis, on the other hand, is well supplied with tiny openings, *stomata* (a single one being a *stoma),* which are breathing pores. Such stomata also occur in the green bark tissues of young stems, but disappear in the older stems.

Most stomata are so small that they cannot be seen except with a microscope. There may be as many as a million on the under surface of a single leaf. All of them wide open at once would not cover more than a hundredth of the whole area of the leaf. Each stoma is bounded by cells that expand and contract, functioning somewhat like a window sash that opens and closes. When the stomata are open, there is an increased amount of evaporation from the leaf; when they are closed, there is less evaporation. The stomata are most often open when the most water is available to the plant. Although the stomata are not always efficient protections to the plant, they often close and prevent too great evaporation when the water supply is scant. When the dust of a city or of a roadside collects too deeply on the leaves, the stomata become clogged and the leaf dies. You may smother a leaf by smearing vaseline or some other grease over its under surface.

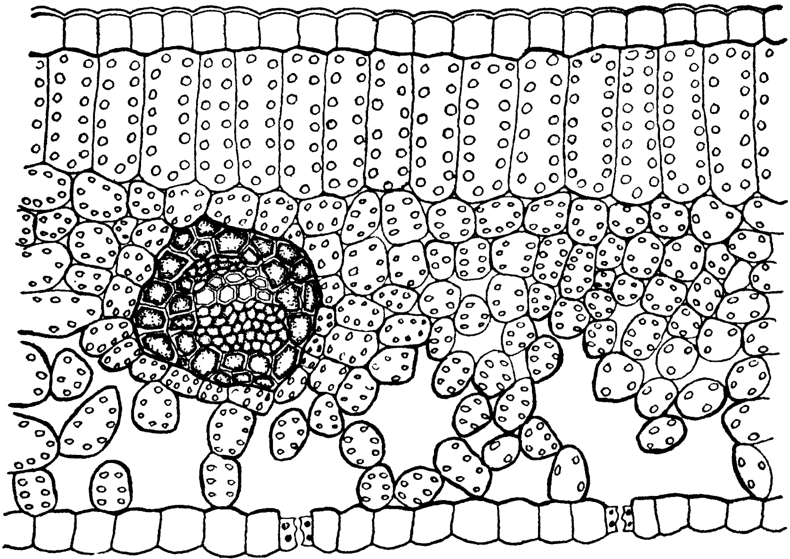


FIG. 137.—SECTION OF A LEAF

Can you find the epidermis, stomata, the cells containing chlorophyll, the air spaces, and a vein? In the vein find the woody cells, those that carry water, and those that carry food from the leaf.

The air that enters these stomata portals goes into microscopic passages that branch and extend throughout the leaf. The part of the air which is used in food manufacturing and the oxygen necessary for respiration pass into these cavities, then through the cell walls, and finally into the cells of the leaf. The waste gases and water vapor pass by the same passages out through the stomata.

Veins.—If a leaf is examined with the naked eye, it is seen to contain hardened, sometimes thickened places, the veins. Veins lack chlorophyll. Therefore they cannot aid in food making. They bear little resemblance to an animal vein, for they are solid masses of cells. On the very outside of a vein the cells are large and thick-walled, so they keep the leaf stiff. The part of the vein nearest the upper surface of the leaf carries water from the stem to the food-making cells. The lower part of the vein carries water and food back from the leaves to the other growing parts of the plant. They are the pipes and tubes by which raw materials are delivered to, and manufactured foods are distributed from, the factories.

Special Forms of Leaves.—All of this applies to common foliage leaves. There are other forms of leaves, however. An onion, lily, daffodil, or hyacinth bulb, for instance, is a compact cluster of fleshy leaves, equipped for the winter storage of foods on which the young plant will feed as it bursts into growth in the spring. The tendrils of many plants, those thread-like twisters which help clematis, peas, smilax, and others to climb, are leaves or parts of leaves. The spines of cacti, or of the barberry which is used in hedges, are leaves or parts of leaves which protect the plant from food-hunting animals, and which in the desert plants reduce the amount of evaporation of water.

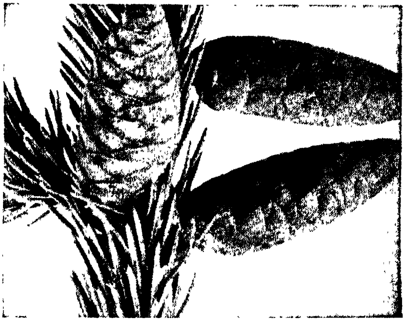


FIG. 138.—MODIFIED FORMS OF LEAVES

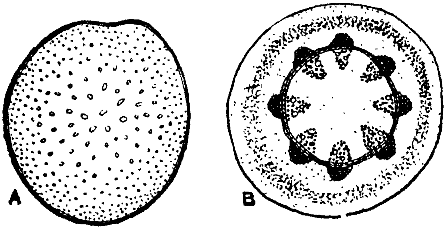
The needles are modified types of leaves, and even the scales of the cones of conifers are modified parts of leaves.

Autumn Colors.—As the summer goes and the autumn nights become cold, the out-of-doors becomes gay with a dress of many colors. The familiar green of the leaves begins to disappear. Chemical changes, often hastened by frosts, are causing the chlorophyll to go to pieces. As it loses its color, it exposes a yellow material which was present in the leaf all of the time although it was previously hidden by the green. The reds of autumn leaves are produced by entirely new materials made in part from the ruined chlorophyll. A number of leaf materials (for instance, tannin combined with oxygen) become brown at this season, and the autumn finally adopts a costume of one color. Each species of plant has its own particular way of going through these changes, and it is a pleasant thing to know the especial beauties of the several kinds of trees in their gay autumnal dresses.

Stems

What are the functions of stems?

They spread the leaves of plants out into the sunlight. Secondly, they contain continuations of the veins of the leaves, and these perform the same functions as the veins. Thirdly, stems may develop (as in trees) quantities of woody tissues which serve as skeletons to support the plant, to hold it up into the sun, and to prevent the winds from blowing it over.



C. J. Quick, Del.

FIG. 139.—STEM STRUCTURES

A, in a monocotyledon; B, in a dicotyledon. Locate the epidermis, vascular bundles, and pith; also find cambium in B.

A young stem, cut squarely across, showing a *cross-section* as we say, would show a structure not so different from that of a leaf. On the outside is an epidermis with stomata. Beneath is a layer of cells containing chlorophyll. Pith cells lie in the center (in dicotyledons, such as the oak), or throughout the stem (in monocotyledons, such as corn). Young pith cells are storehouses for food materials. The veins of stems, more often called *vascular bundles* in this part of the plant, are buried more deeply than those in leaves, and they do not show on the surface.

Vascular Bundles.—In most seed plants the bundles are arranged in a single ring nearer the outer part of the stem, but in monocotyledons they are scattered everywhere. The bundles are continuous with those in the roots, and with the veins of the leaves. The upward flow of water takes place on the inside of a bundle, going from there through that part of the leaf vein which is on the upper part of the leaf. The downward flow of food solutions starts in the lower part of the leaf veins and continues through the outer portions of the bundles in the stems. Although the flow of sap is a well-known thing, it is not so commonly recognized that there is a double flow, with one stream going up and another down.

It should be understood that leaf veins and vascular bundles in stems are not hollow tubes like water pipes. They are more or less solid masses of cells, and of ducts made up of united cells. Some of these ducts, however, may be several inches or even some feet in length. How, then, do liquids pass along them?

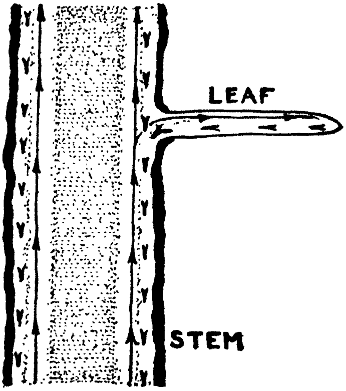


FIG. 140.—DIRECTION OF SAP FLOW

Up-stream deeper in the stem and nearer the upper surface of the leaf; down-stream nearer the under surface of the leaf and the bark of the stem.

Sap Flow.—Much of the sap flow, especially of the movement of the sap within the ducts, is caused by the continual evaporation of water from the upper parts of the plant. As much as a hundred gallons of water may pass from the leaves of an average tree on a summer day. This evaporation provides a tremendous force capable of lifting such quantities of liquid a hundred feet or more from the roots to the top of the tree.

The sap flow from one cell to another, from one duct to another, is perhaps more dependent upon a process called *osmosis*. It is a curious fact that if two solutions are separated by a thin membrane, often only one of the solutions will flow through, ooze through, that membrane into the other. If molasses and water are separated from each other by a thin membrane (like one made of parchment paper), *the water will flow through* into the molasses, but very little of the molasses passes into the water. The flow may even take place directly uphill. In plants the cell walls are the thin membranes through which the liquids flow. The water of the soil passes into the roots and from cell to cell of the plant, in part through the action of this force called osmosis.

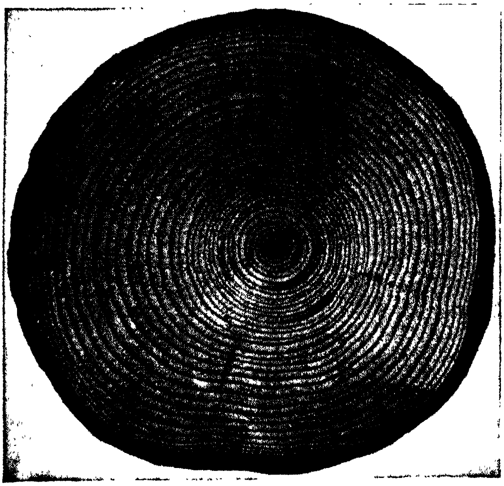


Photo by C. D. Mell. Courtesy U. S. Forest Service

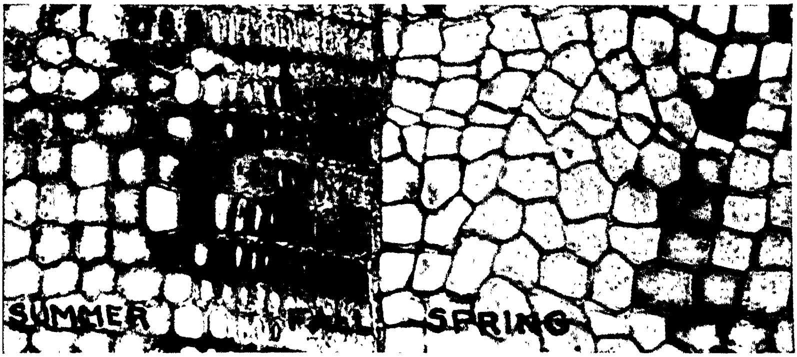
FIG. 141.—RINGS OF ANNUAL GROWTH
In an older, dicotyledonous stem.

Cambium.—If a stem grows for any length of time, especially if it lives for more than a year, its structure becomes changed in part. The outer epidermis becomes bark, dead except for a small portion on the inner margin. Just beneath the bark there develops a thin band of actively growing tissue, the cambium. This layer, wet with sap, is the one in which we are interested when we chew slippery elm or black birch.

Cambium is a very thin layer, often not an eighth of an inch thick in even a large tree. Yet it is the only actively growing part of the older stem. The cells that are formed on the inner side of the cambium become the wood of the tree. Those formed on the outer side become bark.

As spring and a favorable summer progress, the cambium forms new cells that are large, and the whole tissue is spongy.

In the autumn the cells that form are small, and the tissue is compact. These alternate bands of large and small cells are visible to the naked eye only as light and dark rings, the *rings of annual growth*. They occur in both the woody core and the bark, but are most visible in the wood. They furnish some record of the age of the tree, although a midsummer drought or other disaster, followed by a growing season in the fall, may cause two rings to form in a single year. The relative thicknesses of the rings is to some extent a record of climatic conditions, and thus old trees, such as the redwoods of California, furnish information as to conditions in those regions even some thousands of years ago.

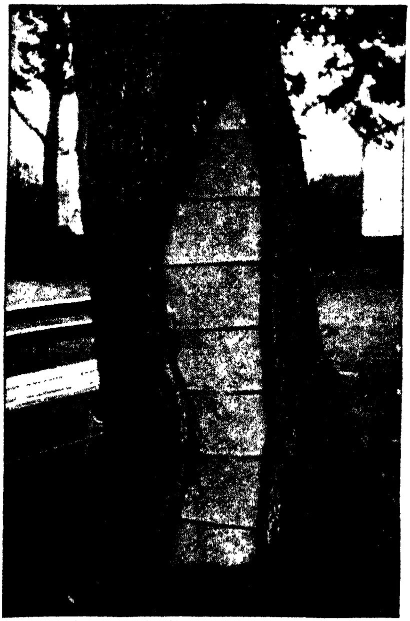


Courtesy National Park Service

FIG. 142.—CELL STRUCTURE IN A RING OF ANNUAL GROWTH

Bark.—A continuous layer of bark on a healthy plant protects the delicate cambium from sun, rains, mechanical blows, fungus, and insects. If the bark is broken, the exposed cambium quickly dries and dies, and fungi and insects find an entrance through which they attack the tree. If the bark is cut continuously in a circle about the stem, *girdled* as we say, the connections between the growing tissues on either side of the cut are broken, and the plant soon dies.

Wood is a material formed by relatively simple chemical changes from the sugar and starch foods of the plant. In our trees that live from year to year, only the youngest wood, the sapwood of the stems, is alive. The older heartwood is composed of nothing but walls of dead cells. It is as dead as a doornail. It still serves to support the tree; but it may be replaced by cement without injury to the tree.



Courtesy Conn. Agric. Exp. Sta.

FIG. 143.—CEMENT MAY SUBSTITUTE FOR THE HEARTWOOD OF A TREE

The buds that occur at the tips of the stems and at the bases of each leaf contain young, very much shortened stems, with young leaves attached. Examine the different ways in which the leaves are wrapped in the buds of different kinds of plants. Cabbage heads and lettuce heads are merely buds, although they are exceptionally well developed.

As a bud opens, its stem lengthens and the leaves become scattered along it. The growth of the stem is due chiefly to the enlargement, by the addition of water, of the cells at the tip of the stem, and to a less extent to an increase in the number of cells and the formation of new tissues. Similarly the growth in roots is confined chiefly to the younger tips.

Roots

Roots are for the most part underground structures. They take water and mineral materials out of the soil and send them on to the other parts of the plant. Roots also hold plants in position, preventing winds from tearing them out of the soil. Roots are often the storage places of food materials, especially during the winter in plants that live more than a year. Certain roots, such as carrots, beets, turnips, and sweet potatoes, contain enough food to attract hungry humans. By spreading underground, roots in some cases (as in blackberries, grasses, etc.) furnish one means of multiplication.

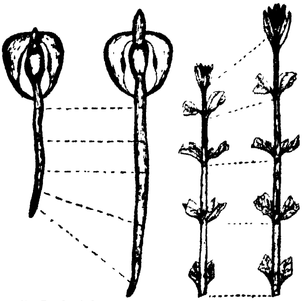

C. J. Quick, Del.

FIG. 144.—GROWTH IN STEMS AND ROOTS
Only the terminal portions lengthen.

The chief difference between a root and a stem is that one grows downward, the other upward. In structure the two are very similar. At the end of each tiny root, however, there is a firm root cap of dead cells which protects the tender growing point that lies behind.

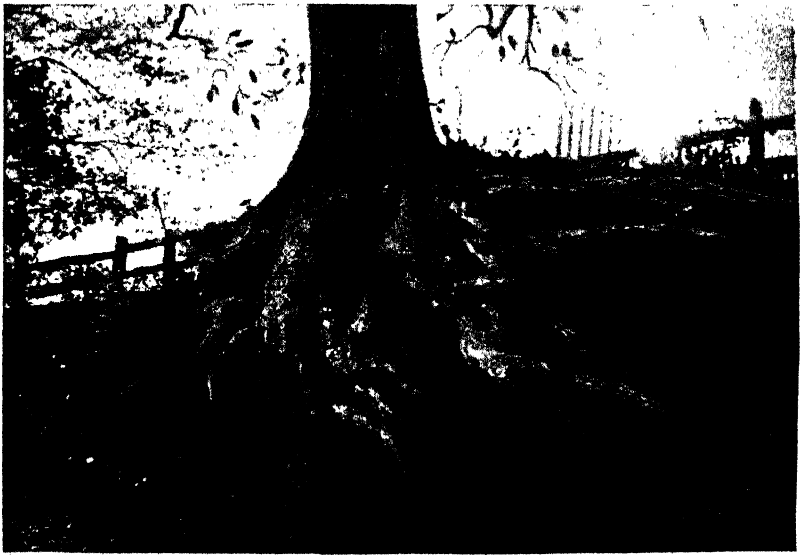

Courtesy J. W. Harshberger, Univ. Pa.

FIG. 145.—ROOTS ANCHOR PLANTS IN POSITION

The end of each root is smooth, but just back of that there is a dense mass of root hairs, tiny projections from the epidermis of the main root. It is through the thin walls of these hairs that water and dissolved mineral materials are taken from the soil into the plant. We do not often see root hairs, for they break off very easily when the plant is pulled out of the soil. Plants which are transplanted have difficulty in "taking hold" in their new locations because with a reduced number of root hairs they cannot absorb enough water to keep up with the amount evaporated through the stomata of the leaves and young stems.

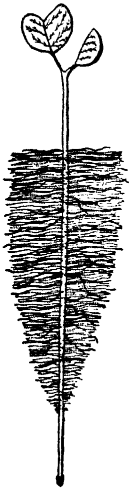

C. J. Quick, Del.

FIG. 146.—PARTS OF A YOUNG ROOT

Note root cap, growing tip, and root hairs.

Flowers

The parts of a seed plant which are chiefly concerned with reproduction are the flowers of the plant, even though (as in grasses and many trees) there is nothing particularly showy about them. Flowers might have been considered in the section on leaves, for most of the parts of flowers, even of the most showy, are modified leaves. But they have very special forms, with special functions.

Examine a flower which has a complete set of parts. A sweet pea, a wild rose, an apple or cherry or peach blossom, a violet, or any of hundreds of others will do.

The very outside of the flower is the **calyx**, composed of a set of green leaves, the **sepals.** They covered the bud before the flower opened. In some instances the sepals are more brilliantly colored, as in a hepatica, iris, anemone (windflower), redbud, or columbine.

The next circle of leaves, the **corolla**, has several **petals.** These are usually brilliantly colored and peculiarly shaped, being the parts of the flower that most often attract insects (see Chapter XXXV).

Within the circle of petals there are several thread-like organs, the **stamens.** These have broadened tops, the **anthers,** that are covered with a powdery, often yellow material, the **pollen.** You have perhaps dusted your nose with this pollen when you have smelled flowers. The pollen produces the male reproductive cells, the sperm of the plant.

In the very center of the flower there is another stem-like organ, the **pistil,** which has an only slightly broadened but often sticky top. The **ovary** is the swollen base of the pistil, and it contains the eggs of the plant. Many flowers have more than one pistil.

In reproduction, the pollen of the stamen is transferred by insects or some other means to the top of the pistil, the grain begins to grow, forming a sort of tube which extends down through the stalk of the pistil to the ovary at the base. A sperm from that same pollen grain moves down through the tube—somewhat after the fashion of the "Squidgicum-Squees 'at swaller therselves!"[1] When the sperm reaches the egg, the two unite, and the egg begins to grow into the seed of the plant. Seeds are thus the direct products of flowers.

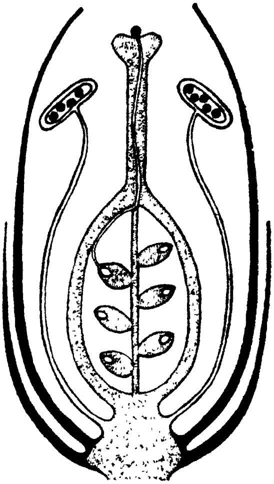


FIG. 147.—PARTS OF A FLOWER, SHOWING FERTILIZATION

Can you find the sepals, petals, stamens, pollen, pistil, ovary, and pollen tube? Each of the larger bodies in the ovary contains a single egg cell.

Any one or more of the floral parts may be lacking in a flower. Of course if both stamens and pistils are absent, the flower cannot produce seed, but it may help some other flower in that process. The yellow leaves at the edge of a sunflower head are such incomplete blossoms, and so are the white ones in the wild hydrangea. These lack both stamens and pistils, but they attract insects to the more perfect, although tiny and inconspicuous flowers in the same cluster. Cultivated flowers are often very incomplete because gardeners have interfered, considering show rather than seed production. This is true of fine and very double forms of roses, of chrysanthemums, of cultivated hydrangeas, and of snowballs, all of which are flowers that rarely produce seeds.

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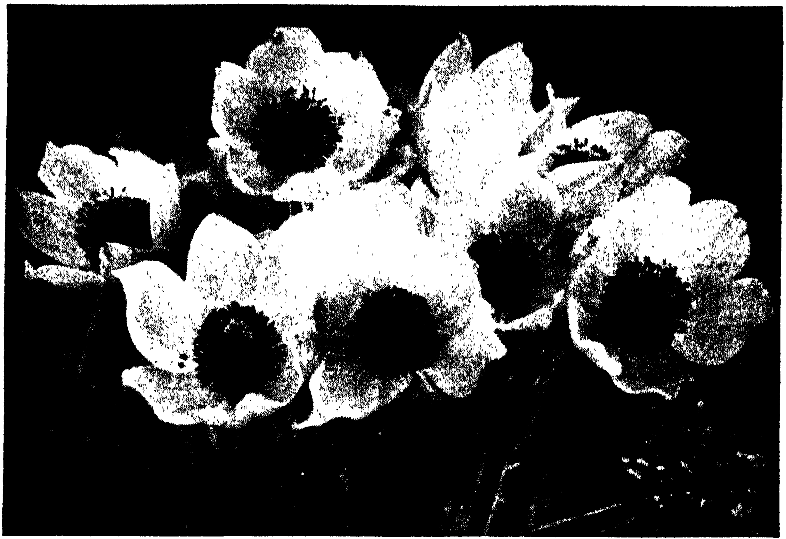
[1] In James Whitcomb Riley's poem, "The Raggedy Man."



Courtesy R. W. Rockwell, Denver

FIG. 148.—SEPALS, STAMENS, AND PISTILS

Colorado pasque flower, a western species of anemone that lacks petals.

Seeds and Fruits

The seed of a plant is an embryo, a miniature plant with leaves and stem and root, the whole protected by a hard coat on the outside. A seed is a young plant temporarily stopped growing until, some day, proper conditions will cause it to continue to grow.

Very often there are pulpy or spiny or feathery or other attachments to the seed. The whole structure connected with a seed is the fruit of the plant. To a botanist a dry maple seed with its wing, or the hard-shelled nut of a hickory, is a fruit as much as a big apple or a juicy watermelon.

Keep your eyes open in the garden, in the grocery store and market, or in the woods and fields, and see what a variety of fruits there are. Try to understand why each has its particular form. Some fruits are little more than seeds with hard, protective coverings. Some are provided with wings by which they are scattered over the countryside, or spines by which they catch hold of passing animals which distribute them, or prickles to keep other animals from eating them, or fleshy pulp for attracting birds that will scatter the seeds after digesting the pulp. Here, as with so many other plant structures, is an endlessly interesting variety of material to be observed.

SUMMARY

1. The leaves of a green plant are organs of respiration, food manufacture, water and food circulation, and food digestion.

2. Chlorophyll, as small chloroplasts widely distributed in the cells of the leaf, aids the plant in the manufacture of its own food. The flat form of a leaf allows the sunshine to reach all of these cells containing chlorophyll. Leaves are so distributed over stems that sunshine can reach each of them.

3. The epidermis on the upper and lower surfaces of the leaf is a waterproof covering. Air enters the leaf through stomata in the lower epidermis. The diameter of these openings is more or less regulated by moisture conditions.

4. The veins of a leaf lack chlorophyll, they serve as skeletons to strengthen the leaf, and provide passages for the circulating water and food in the leaf.

5. Other forms of leaves include fleshy leaves in bulbs, tendrils, spines, the needles and scales of conifers, etc.

6. Autumn colors of leaves are due to the break-down of the chlorophyll, exposing a yellow coloring material, and also forming materials of new colors.

7. Stems spread out the leaves into the sunshine, they contain vascu-

lar bundles which are continuations of the leaf veins and function in the same way, and they develop woody material to support the plant.

8. Young stems resemble leaves in structure. They have an epidermis containing stomata, a layer of cells containing chlorophyll, and pith cells in the center. The vascular bundles are scattered throughout the stem of a monocotyledon; they are arranged in a ring in dicotyledons.

9. Sap flow is due largely to the continual evaporation of water from the surfaces of the leaves of the plant. Osmosis may account for part of the flow of the sap.

10. Older stems develop a bark which protects the internal structures. Wood forms inside. A layer of actively growing tissue, the cambium, is located just under the bark. Rings of annual growth are due to the faster growth in the spring forming large cells, and the slower growth of the later season forming smaller cells. The heartwood of a tree is dead, only the sapwood and cambium being alive.

11. Growth in stems and roots is due to enlargement of the terminal portions only.

12. Roots anchor the plant in position, they may store food, and through their root hairs they obtain water and mineral foods from the soil.

13. In seed plants, flowers are the reproductive structures. The stamens bear pollen grains which contain the sperm cells. These, reaching the pistils, unite with the eggs located at the bottom of the pistil and form the fertilized egg cell.

14. The fertilized egg develops into an embryo which is covered with a hard coat. This is called a seed.

15. The seed with all of its attached structures is the fruit. Fruits are endlessly different in form, serving many different uses.

DEFINE

Leaf
Leaf-mosaic
Epidermis (plant)
Stoma
Vein (plant)
Tendril
Heartwood
Bud
Root
Root cap
Root hair
Flower
Calyx
Pollen

Stem
Vascular bundle
Osmosis
Cambium
Rings of growth
Sapwood
Sepal
Corolla
Petal
Stamen
Anther
Pistil
Fruit

PROBLEMS

1. Why do gardeners wait until the leaves are off of shrubs, or pick them off, before they transplant them late in the fall? (Think of stomata.)

2. Which would most help a dusty bush, water sprayed from above or from underneath?

3. Why should shrubs be trimmed when they are transplanted?

4. In the above trimming, would it be better to take off all of certain branches, or part of the last year's growth on each of the side branches?

5. Bring specimens to class, collected in your home, in some vacant lot, or elsewhere, showing leaves with other than the usual flat form.

6. Similarly bring specimens showing stems with other than the usual stem forms.

7. Prepare a list of the trees whose autumn colors you can describe.

8. Make a detailed comparison of the structure of a green plant leaf and a factory.

9. Explain what is happening when a leaf wilts.

10. Why does a plant sometimes wilt even though the soil in which it stands is well supplied with water?

11. In using leaves for indoor decoration, would you pick stems bearing old or young leaves? Explain.

12. Why do gardeners find the late afternoon the best time of day in which to water a garden? (Think of stomata.)

13. Potatoes will keep firm and heavy in storage until sprouts grow out on them; then they become much shriveled and lose weight. Explain why.

14. What would be the simplest way in which a small boy might kill a whole tree?

15. Would it do much damage to a tree to cut off its leading shoot (its top one)? Why?

16. By mowing down bushes in the summer, it is possible to clear a pasture land of most of its brush. Why is it that the same process may not kill the brush if performed in the winter?

17. Should shrubbery be pruned in the winter, spring, summer, or fall? Explain.

18. A fine wire, tightly twisted about a tree trunk, may kill the tree, or it may cause a swelling of the trunk on one side of the wire. Will the swelling develop above or below the wire? Explain.

19. If a chicken-wire fence were nailed onto living tree trunks, what

precautions would you have to take to keep the top wires from being stretched apart from the lower wires as the trees grow? Explain.

20. In determining the age of a tree by its annual rings, would it make any difference whether you counted near the base or near the top of the main trunk? Explain.

21. Why does wood split more easily with than against the grain?

22. Knots are often found deep inside of a log, even when there are none on the outside. Explain.

23. Which will have more knots, a log from a tree grown in the open or one grown in a dense forest? Explain.

24. In tapping maple trees for syrup, is it better to put the spigot deeply or shallowly through the bark?

25. By one method, new plants are produced by cutting off a ring of bark around a stem, and bending that stem into the ground or into moist moss at the cut point. Will the new roots appear above or below the cut ring? Explain.

26. Cut flowers may be kept fresh for a longer time if a little salt is added to the water in which they are placed. Explain.

27. Explain how it is that salted meats do not decay.

28. Why do we become thirsty after eating especially salty or very sweet food?

29. Will dried fruit swell more when cooked with or without sugar in the water?

30. Will fresh fruit cook down to sauce more quickly with or without sugar in the water?

31. How can you explain the fact that plants usually grow faster at night, although they are manufacturing more food in the day?

32. What plants do you know that are practically stemless?

33. Botanists consider a potato tuber a stem. Why?

34. Give at least three reasons why trees often fail to thrive in a city.

35. Many edible roots, like those of parsnips, evening primrose, etc., taste sweeter in the early spring than they did in the fall. Why?

36. Which is the best and which the poorest method of transplanting things: to shake the dirt off the roots; to leave the dirt on the roots; to wash the dirt off the roots? Why?

37. Is the root system of a plant likely to spread farther in rich or in poor soil? Explain.

38. Why are root hairs entirely absent from the older portions of a root—for instance, of a tree?

39. Are house plants best watered by being sprayed, by having water put on the soil, or by letting the pot stand in water for a while? Explain.

40. A tree that has grown in a dense forest has all its neighbors cut from around it. Is it more or less likely to be blown down than a tree that has always been in the open? Explain.

41. In soil free of stones, do the main roots of all kinds of plants grow directly downward? Prove your answer.

42. Such root crops as potatoes, carrots, beets, and turnips produce large crops only when the soil is kept loose and well-cultivated. Why is this so?

43. Why is a tree likely to die if it has a foot or more of soil filled in for some distance around its trunk?

44. Make a list of fruits you know, including 25 kinds that are as different as fruits can be.

45. In a corn plant, what are the structures which we call the ear, husk, tassel, and silk?

46. Make a list of plants of which we commonly eat the leaves.

47. Make a list of plants of which we commonly eat the stems.

48. Make a list of plants of which we commonly eat the roots.

49. Make a list of fruits which are commonly sold in the markets in your part of the country.

50. Make a list of plants which furnish fibers useful to man. In each case, which part of the plant is it that furnishes the fiber?

51. Why do we commonly press the soil down (often by stepping on it) around seeds which have been planted, or about the roots of plants that have just been transplanted?

52. Why do water-inhabiting plants so often lack roots?

53. Make a list of the occupations, trades, or professions in which a knowledge of plant structures would be of practical, dollars-and-cents importance.

CHAPTER XIV

REPRODUCTION

Let me tell you one of the most interesting stories of all biology.

We have just learned how new seed plants come into existence by the union of the sperm and of the egg in the ovary of the flower. But let us consider how new organisms of other kinds come into being.

Spontaneous Generation

Centuries ago it was believed that new living things just happened out of dead stuff. Spontaneous generation, the theory was called. Frogs and toads that were found in the mud puddles of the road were supposed just to have rained down out of the sky, and to have come from the very raindrops. Certain hard-shelled sea animals, the barnacles, were thought to originate from the rocks on which they grew, and then later to turn into geese. Van Helmont, a famous Belgian writing about 1600—only three hundred years ago—believed that living mammals originated through the fermentation of dead stuff. He gave this formula for producing mice: "Place some dirty rags together with a few grains of wheat, or a piece of cheese, in a dark place, and in a few days they will be transformed into mice." The maggots that were found in decaying meat were supposed to have come from the dead meat itself. Even today there are people who believe that a dead horsehair placed in a watering trough may become a living snake!

But as men began to look at things more closely it was found that the frogs had come originally from eggs, and that the adult animals had been hiding in the woods until the rain made puddles in the roads. And when a piece of netting was put over the jars containing the meat, it was found that no maggots grew in it; because, as further observation showed, no flies were able to get at the meat to lay eggs which would grow into maggots. Maggots are merely the younger stages of flies.

The spontaneous generation of insects was disproved over two hundred and fifty years ago by an Italian, Redi; but it was less than three-quarters of a century ago that Pasteur, the famous French scientist, finally proved that even the microscopic plants and animals have living parents. It is now very certain that *life comes only from life.* All living organisms come from previously existing living organisms.

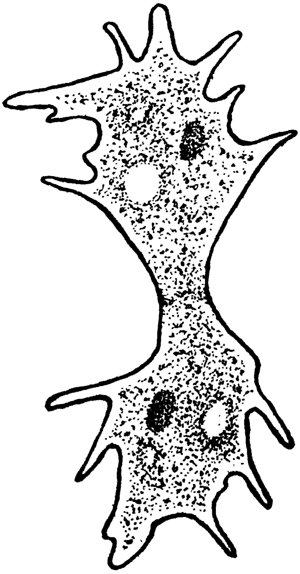


FIG. 149.—A PROTOZOON REPRODUCING ASEXUALLY

Asexual Reproduction

The very simplest way in which a new organism may arise is to have an old one split in two, when, behold, there are two creatures in place of the one. This very simple process is called *asexual* reproduction, which means reproduction without sex. It is the method employed by almost all of the simple organisms, such as the protozoa, bacteria, and many of the algæ. Sometimes even higher plants reproduce asexually, as when potato plants grow from eyes that have been cut out of an old potato, and when whole willow trees start from stems that have been placed in water.

We have seen that in one of their alternating generations such plants as mosses and ferns develop special reproductive parts called spores. When these drop from the parent they are immediately ready to grow into new plants. A spore is therefore a means of asexual reproduction, and it is not at all like the seed which comes from the union of an egg and a sperm.

Sexual Reproduction

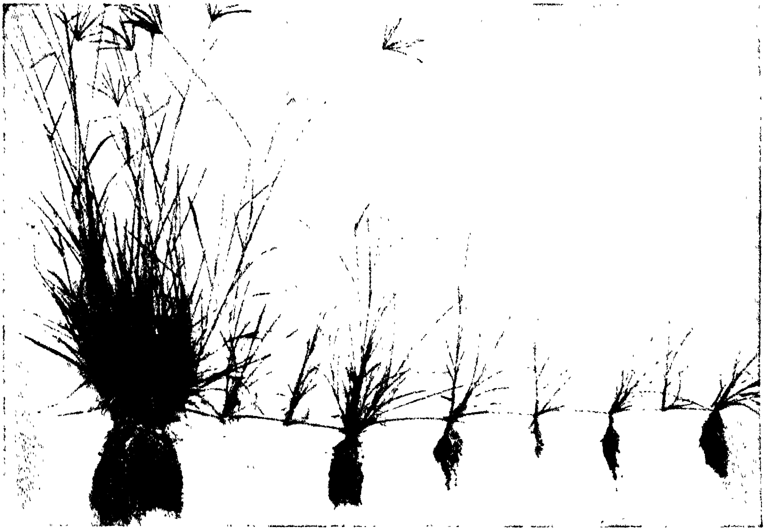
Now, for some unknown reason, simple, asexual reproduction has been replaced among most of the higher plants and animals by sexual reproduction. Each kind of sexual organism exists in two forms, a male and a female.

Eggs and Sperm.—Special reproductive or *germ cells* are produced by these individuals. The female produces *eggs*, and the male produces *sperm*. Before a new individual can come into existence it is necessary that an egg and a sperm come together and unite.

We have learned that the eggs of a plant or animal are produced in an organ called an ovary. Eggs are ordinarily large cells, often containing much food material. Most eggs do not move.

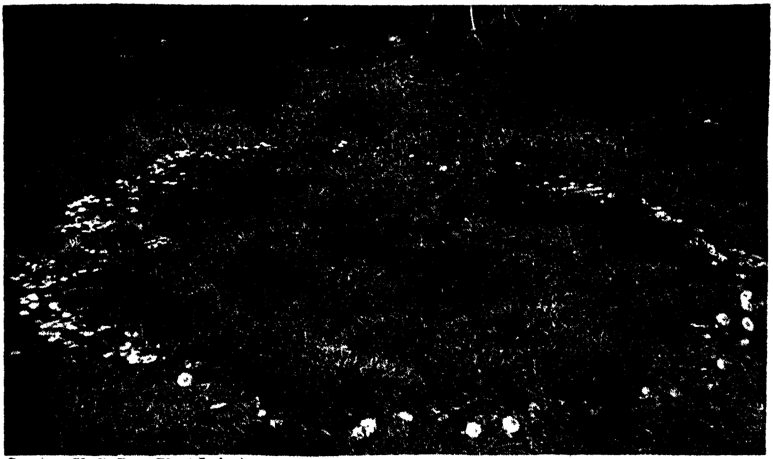
We have also learned that sperm are produced in seed plants from yellow, powdery grains called pollen, and in the testes of animals. Sperm are usually very microscopic cells, often thousands of times smaller than the eggs of the same species; and most animal sperm are curiously shaped, usually bearing very long, very slender tails by means of which they are able to move about through liquids.

Fertilization.—Thus a sperm may move about until it reaches and enters an egg. When the contents of the egg and the sperm have become thoroughly mixed, *fertilization* has occurred. There is no longer an egg and a sperm, two things, but one single thing, a new thing, a fertilized egg cell. This cell is the beginning of the new individual. Before fertilization the egg was unable to grow, but a fertilized egg can grow. It may finally grow into a fully developed plant or animal.



Courtesy U. S. Bur. Plant Industry

FIG. 150.—ASEXUAL REPRODUCTION IN A GRASS

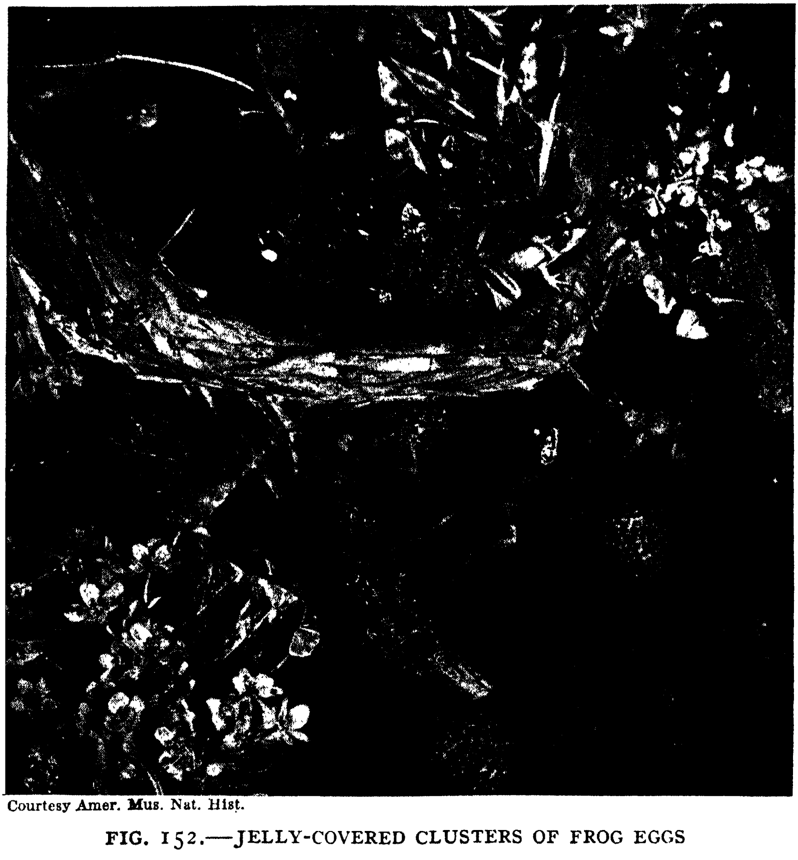


Courtesy U. S. Bur. Plant Industry

FIG. 151.—ASEXUAL REPRODUCTION IN MUSHROOMS
The original clump spread by underground growths to form this "fairy ring."

We have already seen how the pollen of a seed plant is transferred to the pistil, and how the sperm reaches the egg in the ovary.

In animals, the egg and the sperm are brought together in a variety of ways. Among fish, the females lay their eggs, often in great numbers, in the waters in which they live. The males coming along at some later time then shed their "milt," which is sperm in a liquid secretion, in the water near the eggs. Some-



Courtesy Amer. Mus. Nat. Hist.

FIG. 152.—JELLY-COVERED CLUSTERS OF FROG EGGS

times these sperm reach the eggs and fertilize them, but of course this method involves much waste.

Among the toads, eggs are not produced until a male comes along ready to shed sperm, and thus fertilization is more likely to occur here than with the fish. Among other higher animals, including the insects, reptiles, birds, and mammals, the sperm are placed directly into the body of the female, where they have still better chances of meeting the eggs.

Care of Developing Eggs.—The fertilized eggs and the developing young of animals are cared for in the following fashions: Fish eggs are protected with only thin shells, and are usually laid without much care in a stream or lake or ocean. Enemies destroy the great majority of them, and only one or two in many thousands ever survive. The eggs of frogs and toads are better protected by being placed in masses of thickish jelly. Bird eggs, as you know, are still safer in their hard shell coverings, and the adult birds carefully tend them until the young birds have hatched.

Most reptiles lay their leathery-shelled eggs on the ground several weeks before they hatch, but sometimes that tiny, beautifully marked species, the ring-necked snake, does not lay its eggs until a few days before they are ready to hatch; and sometimes the mother even keeps them within her body until after they are hatched, and the young are consequently born alive. In such cases the mother's body furnishes excellent protection for the developing babies. All of the mammals similarly protect their young within the bodies of the mothers. Here, as often, we find a remarkable efficiency in natural processes.

Reproductive Instincts

An animal knows how to do the things necessary for perpetuating its kind because it is born with what we call reproductive instincts. A bird builds its nest, lays its eggs, incubates them for long and weary days, and finally feeds the young after they hatch. The mother works her little head 'most off without knowing why she does it or having to learn how to do the necessary things. Her instincts guide her. It is fortunate for the coming babies that that is so.

Salmon.—As an instance of the workings of these instincts consider the Pacific salmon. They are hatched high in the mountains near our western coasts, for only cold and dashing streams provide favorable homes for the young fish. But adult salmon thrive best in the salt sea, and there the growing fish soon go to live.

Courtesy Dr. A. A. Allen, Cornell Univ.

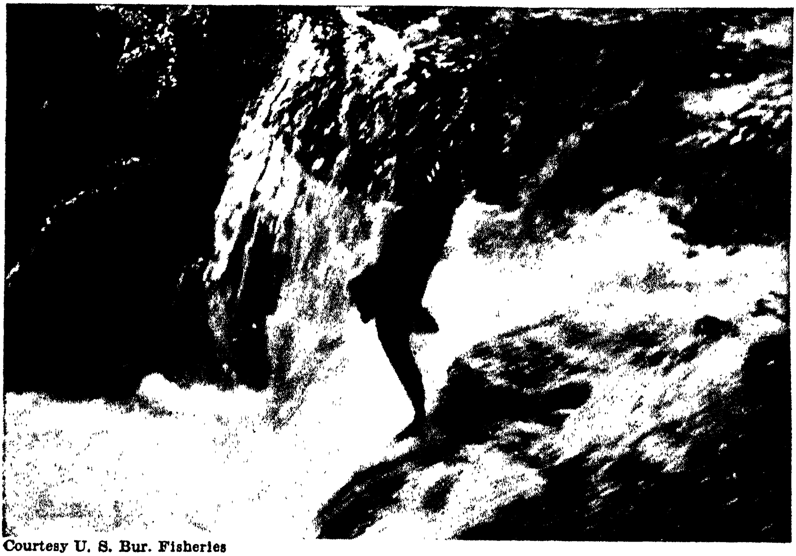
FIG. 153.—WORKING ITS LITTLE HEAD 'MOST OFF

Humming-bird about to feed its young.

Nevertheless, at the end of several years, when their reproductive instincts develop, they become uncomfortable in the ocean, and the cold waters of some stream lead them away from the sea and back to the headwaters and to the shallow waters of the mountain places. In this return migration thousands of adult fish swim against the strong currents, and jump and struggle from ledge to ledge and up over the waterfalls to the places where their eggs must be laid. Often their journeys are as long as one or two thousand miles, and all of the way against the rushing torrents.

While fat and vigorous fish start the trip, only thinned and exhausted animals reach the mountain fastnesses. Fishermen must catch their food salmon early in the up-stream drive. In the headwaters the fish lay their eggs and cast their sperm, and fertilization occurs. Then most of them die, having spent themselves for the young that are to be.

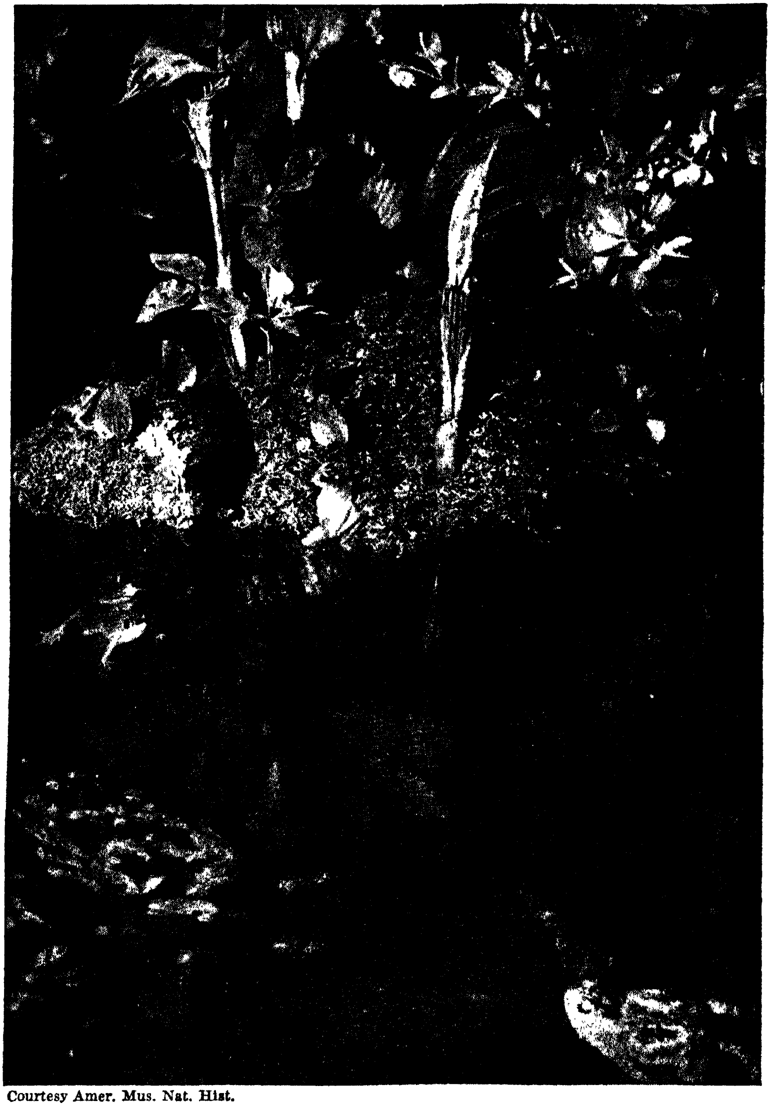
Toad.—As another illustration, listen to the story of Old Toad who was born in a pond. There he lived as a tadpole, but when he grew his legs and hopped onto the land he lost his interest in the water and travelled far and far away. In the woods, in the gardens, digging, taking dust baths—so through the year he lived with never a thought of deep water. When the fall came he burrowed into the ground, down beneath the leaves, and there he slept through the winter.



Courtesy U. S. Bur. Fisheries

FIG. 154.—SALMON MIGRATING

But when he awoke one day in the spring he was a different toad crawling to the surface. For one thing, he was splitting off his old skin and eating it, exposing a brand-new suit of clothes. And, a still more important thing, this was a creature with a liking for water, whose business in life was to get out



Courtesy Amer. Mus. Nat. Hist.

FIG. 155.—FROGS AND TOADS IN THE POND
Early May in southern New England.

of the woods and back to the pond. There he must go to fertilize the eggs that were going to be laid.

Have you ever seen the spring-time migration of the toads? 'Tis worth watching. From everywhere they come, hop, hop, hop, all intently hopping, not easily distracted, for they are very intent on getting to the mating! About the pond the air becomes alive with shrill songs. If you approach quietly and watch the water carefully, you may see them in pairs, the males there to shed sperm as the eggs are laid.

Honeybee.—Finally, here is the story of the mating of the queen honeybee. Part of this you may see for yourself, some spring day, if you know where there is a beehive. Much the same thing occurs with some kinds of ants, and it is very easy to watch their mating swarms in the late spring or the summer.

There is usually but one queen in a beehive, and she is the one that lays the eggs for the colony. Most of the bees are workers, and they are also females, but they ordinarily lay no eggs. The males are the drones, and they do no work.

When a new, young queen first comes out of a wax cell, she stays close to the dark of the hive; but one day things change and she goes to the door and out into the open. This is at the mating season. If the day is not good, if it is too cold or too windy, she will go back into the hive and wait. But finally, when the right day comes, the young queen steps out onto her door-sill, ready to engage in the mating.

She stretches her wings. They are fine, strong wings, but they have hardly yet been used in flight, and now they must undergo a severe test. Will they suffice? A moment, just a moment to question—and now she is off—a bee—now a speck—now but a tiny speck high in the blue!

All the near-by drones, aroused to excitement, have rushed after the young queen; but the flight is too swift and the weaker ones are already returning.

And now it may be higher than your eye can follow. The falling males must tell the story. Only the most vigorous drones are able to follow the female in her flight. The crippled ones, the weak ones, and those that have been starved, are dropping out. Very high in the blue but a half dozen drones, now but two or three, are following the young queen; until, with one final, supreme effort, she goes still higher—where only one male can follow.

The mating occurs in the air; the drone loses his life in the process; and the sperm are stored in the female to be used gradually throughout the years of her life, to fertilize the eggs of a whole colony.

Courtesy A. I. Root Co., Medina, Ohio

FIG. 156.—DRONES AT THE DOOR OF A HIVE

Late in the fall of the year.

And the sperm that will be used will have come from the male, the one male, who was most fit for the mating!

SUMMARY

1. For many centuries men believed that at least some living things came into existence out of dead stuff. Now it is thoroughly established that all living individuals have come from other living individuals.

2. Many of the simplest organisms give rise to new individuals merely by dividing into two. Such simple division is one type of asexual repro-

duction. Spores provide a means of asexual reproduction for many fungi, mosses, ferns, and other organisms. Even seed plants may reproduce asexually by buds, cuttings, root suckers, etc.

3. Most higher plants and animals reproduce sexually. Each species exists as male and female. These produce special germ cells, the sperm and the eggs. An egg that is fertilized (*i.e.*, has united with a sperm) differs from an unfertilized egg in its ability to grow into a new individual.

4. The eggs and sperm are brought together in plants usually by wind or insect carriage. Among animals the less efficient means occur in the lower vertebrates, such as fish and amphibia.

5. The developing eggs are poorly protected among fish, but they are protected by hard shells among the birds. Among the mammals they are retained in the body of the mother until the young are well developed, and thus the young are born alive.

6. Reproductive instincts, such as those of the Pacific salmon, the toad, and the honeybee, provide efficient means for bringing into existence and caring for the young of the new generation.

DEFINE

Spontaneous generation
Asexual
Egg
Sperm
Fertilization

PROBLEMS

1. What common garden plants, shrubs, or trees are commonly grown asexually, instead of from seed?

2. Is asexual reproduction more common in animals or in plants? Prove your answer.

3. Report every case you can find of people who, today, still believe in spontaneous generation.

4. Show how it is that weather conditions at apple-blossom time may affect the size of the apple crop in the autumn.

5. Do animals that produce great numbers of eggs always raise the largest numbers of offspring? Explain and give instances.

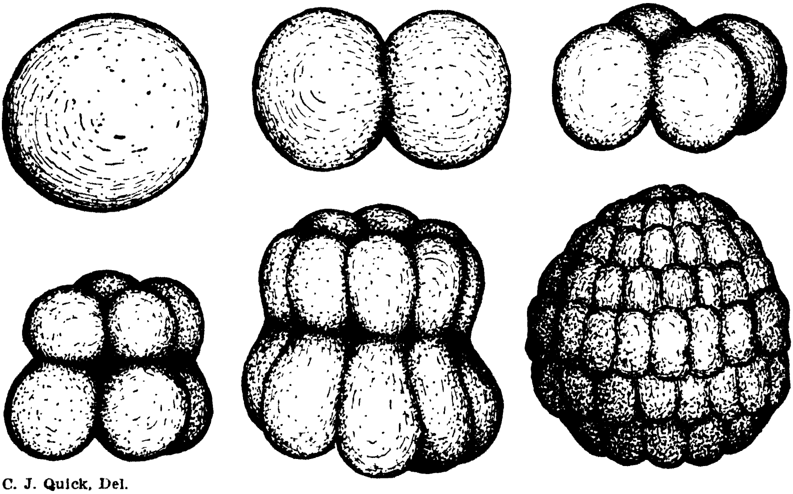
6. Give particular instances, from your own observations, of the way in which fish, birds, or insects care for their young.

7. Which does Nature consider the more important, the life of an individual or the life of a species? Find proofs in this chapter.

CHAPTER XV

EMBRYOLOGY

The new plant or animal has come into existence as a fertilized egg cell. But the egg doesn't resemble the grown organism. How do the tissues and organs develop from the simple, one-celled beginning?



C. J. Quick, Del.

FIG. 157.—EARLY EMBRYONIC DEVELOPMENT
The single cell divides into two, the two into four, and so on.

It was formerly imagined that within each egg the plant or animal existed perfect and complete, only very minute in size. It was believed that such a miniature must exist even though it had never been visible to human eyes. But we now know that such an idea was pure imagination and untrue.

All of the complicated structures of an organism—of a tree, of an insect, or of a human—come into existence by a series of gradual changes beginning with the single, fertilized egg cell. Bit by bit, cell by cell, the structures of the perfect organism are builded. The study of the form and structure of the very young and developing creature, of what we call the embryo, is that one of the morphologic sciences which we call *embryology*.

Embryonic Development

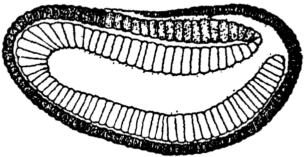

C. J. Quick, Del.

FIG. 158.—THREE PRIMITIVE LAYERS OF CELLS

Only two layers have formed in the lower wall of the embryo. The digestive tract is forming in the center.

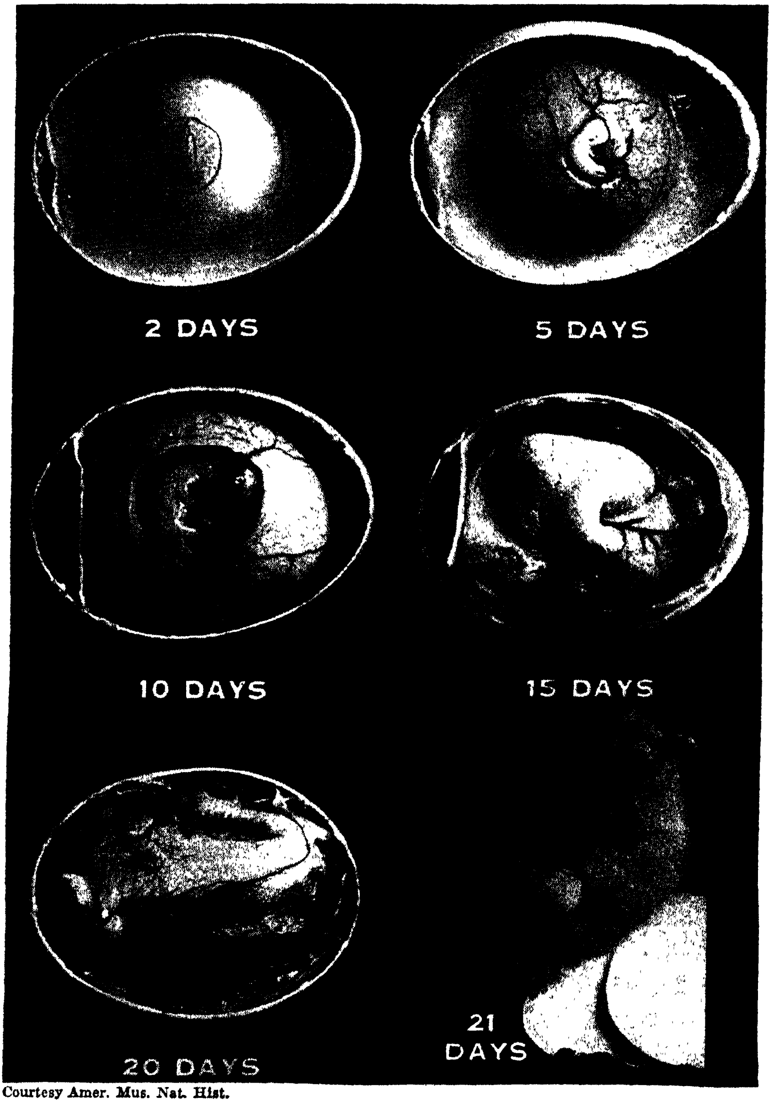
Cell Division.—First of all, the single cell of the egg begins growing by dividing into two halves, forming two cells where there had been but one before. The two cells are distinct, but more or less fastened together, as all cells are in plant and animal tissues.

Then as growth proceeds the two cells divide into four, the four into eight, the eight into sixteen, and so on, until after some time a whole mass of cells has developed. This is true of most of our plants and animals.

Germ Layers.—In the next place the cells in this mass begin to show differences. In animals, for instance, three different groups of cells become apparent. Each of these forms what is called a *primitive germ layer* of cells. These are the first beginnings of real organs.

Each of these layers will finally develop into a particular group of organs. From one layer (for instance, in the vertebrates) the integumentary (skin) and the nervous (brain, nerve, and sense organ) structures will develop. No other organs will ever come from this layer of cells.

Similarly the other organs come from one of the other two layers. The whole story is too complicated to tell here. It is enough now to know that early in the life of the embryo the



Courtesy Amer. Mus. Nat. Hist.

FIG. 159.—EMBRYONIC DEVELOPMENT OF THE CHICK
Gradually the structures develop. Finally the embryo becomes the perfect chick.

cells begin to group to form organs. This happens with a chick embryo, for instance, within a few hours after it starts growing. The layers are usually formed before the egg leaves the body of the hen.

Chick Embryos

Open the eggs of a hen, every six or eight hours during the first four or five days of development. With your naked eye you may watch the gradual formation of the several organs. It is a most interesting thing to follow. I have seen many a farmer astonished when he first saw this development going on in the eggs, although he might have known it years before had he been curious enough to open eggs from an incubator or a setting hen.

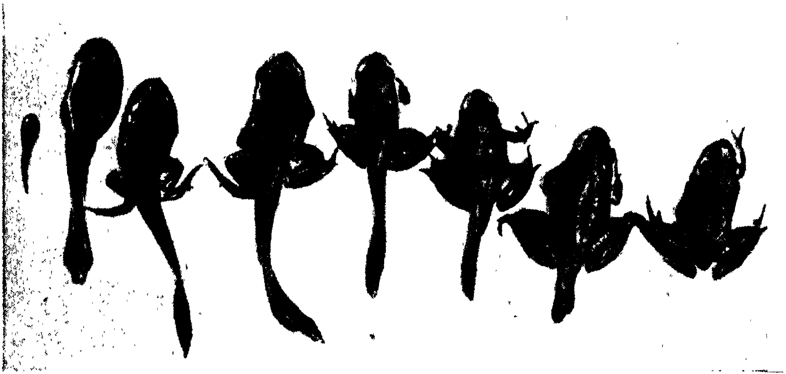
Remember that the living, growing protoplasm of a hen's egg is at first only a small part of the material within the shell. If a fresh egg is allowed to stand quiet for a time, the growing embryo will be found as a small spot floating on the top of the yolk. This is what the farmers call the "germ" of the egg. The yolk is food material; it too is part of the egg. The white and the shell are not really parts of the true reproductive cell, for they are added after the egg leaves the ovaries of the hen.

The accompanying figures will show some of the things you may see in a series of hen's eggs, opened as incubation proceeds. In the early stages there is little resemblance to a bird. Only gradually, bit by bit, do the newly growing cells form into tissues and organs. At first each structure is very simple, but it gradually becomes more and more complicated until finally it takes on the shape of the perfect organ and is the perfect organ. Note this in connection with the development of the head structures of the chick.

At the end of three short days of growth the young chick has most of its organs in general outline. It takes another eighteen days for the birds to hatch, and all of that time is taken with the finishing off, as it were, of each organ, and the setting of those organs to work.

Recapitulation

One of the striking things about embryonic development is the fact that, in a general way, the embryo of each plant and animal begins to develop in about the same way as the embryos of all of the creatures below it in the scheme of classification. This method of development by passing through a series of stages which resemble those of lower forms of life is called *recapitulation,* a word meaning a recountal, or a rehearsing of events.



Courtesy Nature Magazine

FIG. 160.—GRADUAL DEVELOPMENT OF THE TADPOLE

Each species, however, goes further in its embryonic development and forms more complicated structures than any of the simpler species through whose forms it is passing. The last stages of development are the ones that finally make an organism most different from the lower ones. For instance, when the chick was in a one-celled stage, it in general resembled a protozoon. When it was a hollow mass of cells, it was something like a polyp animal. Much later, when it had a long tail and gill openings, it bore a superficial resemblance to a fish-like animal. Only finally did it become an out-and-out bird.

A rather similar order of embryonic development occurs in all of the animals. Even the human embryo passes through each of these, as well as through many other stages. The human embryo at one time in its development also has gills and a tail.

In a general way, such recapitulation also occurs among the plants. Thus, the seedlings of practically all of the conifers bear needle-like leaves, although the mature conifers differ considerably in their leaf characters. The leaves of the mature pine, for instance, are long and slender needles, and those of the mature cedar are very small and flattened scales; but both of these trees have similar leaves in their embryos.

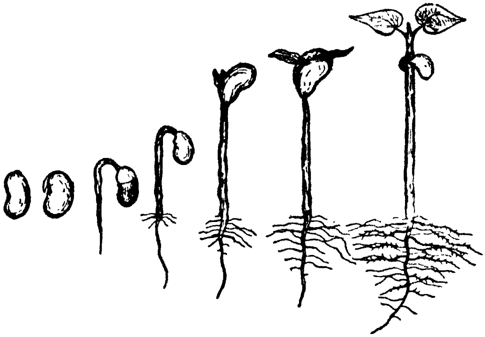

C. J. Quick, Del.

FIG. 161.—GRADUAL DEVELOPMENT IN A BEAN EMBRYO

It must be understood that the *resemblances in recapitulation are all very superficial.* The chick never is a real polyp; never a real fish. It resembles them only in a very general way.

The resemblances, however, are enough to make us wonder why they should be so. The gill openings of a bird or of a human embryo are never connected with true gills. Such structures are of no use to these higher animals. They disappear before birth. Why do they ever form?

The answer which biologists generally give is that the higher organisms must have had lower ones as their remote ancestors, millions of years ago. It is as though they had climbed a flight of stairs. In reaching any one step they have passed over the lower ones; and each embryo still has to climb the ancestral stairs in the course of its embryonic development.

Feeding the Embryo

Shut up within the shell of its egg, or within the body of its mother, the embryo must have some special means of securing food. The digestive tract is not formed in the young animal, and food cannot be delivered by way of it. Nourishment must be received directly into the blood, and waste materials must be carried away by the same stream.

Courtesy R. W. Rockwell, Denver

FIG. 162.—YOUNG MEADOW MICE

In Birds.—The source of the food of an embryo bird, as with many of the lower animals, is the yolk and the white of the egg itself. Very early in the life of the chick blood vessels grow out around the yolk, far beyond the true body of the embryo. These carry the food back to the chick (as shown in the figures of chick embryos in this chapter).

In Mammals.—The eggs of mammals contain little food material, and mammal embryos must obtain their nourishment from the blood of the mother in whose body, you will recall, they are kept during development. Food materials from the mother's blood pass into the blood of the embryo.

But note that even with the mammals the mother contributes no living materials other than the egg from which her offspring grows. The quantity and quality of the food which the embryo gets may decide whether it will starve or prosper; but there is no way in which the mother can affect the hereditary characters of her offspring after embryonic growth has begun.

Surely these are interesting stories of biology!

SUMMARY

1. New individuals come into existence as single cells (the fertilized egg cells).
2. By a process of cell division the single cells divide into two, the two into four, the four into eight, and so on until there is a mass of many cells.
3. In animals this mass of cells divides into three groups, the primitive germ layers. Each layer is the beginning of a particular organ or a group of organs.
4. Thus all of the structures of the mature plant or animal develop from the single cell by a series of gradual changes.
5. Each species, in its embryonic development, goes through a series of stages representing in a general way the embryos of the organisms below it in the scheme of classification. This process, known as recapitulation, suggests that these higher organisms must have had ancestors which were similar to the simpler organisms.
6. The bird embryo is fed on the yolk and white which are in the shell with it.
7. The embryos of the mammals are nourished with food from the blood of the mother; but no living blood of the mother ever reaches the embryo.

DEFINE

Primitive germ layer	Embryology
Embryo	Recapitulation

PROBLEMS

1. Can you see any advantage in having the chick embryo begin growth (in large part) with the head structures?

2. How is the young plant embryo fed? (The answer has been given in previous chapters.)

3. Are the most important agricultural crops obtained from plant leaves, stems, roots, flowers, or fruits? Explain why this is so.

4. Is there any relation between the length of embryonic development and the condition of the bird when hatched (feathered or naked, helpless, or able to run about)? Illustrate with familiar birds.

5. After studying the figures of chick embryos shown in this chapter (or, better, after studying actual embryos in the laboratory), make a table showing what structures have changed and how they have changed between each stage shown.

6. Do the same for the amphibians shown in Figs. 42 and 160.

7. Do the same for the beans shown in Fig. 161.

8. In a plant embryo, which organs develop first? Why?

9. In this chapter we have given more attention to animal embryos than we have to plant embryos. Why?

10. Identical twins are two or more individuals which have developed from a single fertilized egg. How must normal embryonic development be modified to give rise to such twins?

11. What modification of normal embryonic development would produce a double-headed monster?

12. How much of a living hen's egg is really alive? This is a subject for debate.

13. Which keep better for human food, fertilized or unfertilized eggs? Why?

14. Can you give an instance of an embryonic or larval structure which does *not* illustrate recapitulation?—an embryonic structure which is not like anything to be found in the simpler ancestors from which the creature is descended?

15. There are a few insects which are *viviparous*—that is, the eggs hatch inside the parental body and the young are born alive. From reference literature, try to find which common insects are viviparous.

MORPHOLOGY: REVIEW

1. Be prepared to define all words listed at the ends of Chapters XI through XV.

2. Review all of the summaries at the ends of those same chapters.

3. Review the problems given at the ends of those same chapters.

4. Explain what is meant by each of the following statements. These are the important principles in that part of Morphology which we have studied.

CHAPTER XI. **Living Structures.**—Morphology is the biologic science in which the form and structure of organisms is studied.

Living creatures are built of organs and tissues, each with a definite function to perform.

The organs of different groups of plants and animals differ considerably in structure. The organ systems of a vertebrate are good examples with which to become acquainted, because we ourselves are vertebrates.

Tissues are built of cells. These are the simplest units of structure, although a cell has numerous structures within it.

CHAPTER XII. **Animal Structures.**—We have examined the structures of an insect, because it is neither the simplest nor the most complicated and therefore a good form with which to begin; of an earthworm, because it is a somewhat different type of simple animal; of a frog, because it is a simple form of vertebrate; and of the human, because of our personal concern with that species.

CHAPTER XIII. **Plant Structures.**—The leaves, stems, roots, flowers, and fruits are the parts of a seed plant. Each is so constructed that it performs several functions in the life of the plant.

CHAPTER XIV. **Reproduction.**—All living creatures have come from previously living individuals.

Among the higher plants and animals the union of an egg and a sperm gives rise to a fertilized egg cell which differs from an unfertilized egg in its ability to grow.

The sexual reproduction of higher animals often involves remarkable ways of accomplishing fertilization and the care of the young.

CHAPTER XV. **Embryology.**—New individuals come into existence as single cells, and the structures of the mature plant or animal develop from this simple cell by a series of gradual changes.

Each organism in its embryonic development repeats, in a very general way, the ancestral history in passing from simpler to more complex forms.

While the bird embryo secures its food from the yolk of the egg, the mammalian embryo is fed on food materials from the blood of the mother.

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*Books recommended as the best volumes for a high school reference library.

UNIT IV

Functions Among Plants and Animals

◆

The Biologic Science Called

PHYSIOLOGY

◆

PROTOPLASM
BUILDING FOODS AND PROTOPLASM
USING FOODS AND PROTOPLASM
HUMAN HEALTH
DISEASE
CARRIERS OF DISEASE
IMMUNITY TO DISEASE

Preview

Look at the following questions. Would you like to know the answers to them? They are all to be found in this unit on physiology.

1. Which organisms have learned to store and use sunshine?
2. Is it better to have the living stuff, of which our bodies are made, alive, dead, or dying?
3. Why are men so rarely more than six feet in height?
4. Why is the smallpox death rate in parts of the United States fourteen times as great as that in Japan?
5. Do plants really go to sleep? Why?
6. Why do clean teeth sometimes decay?
7. Where does a plant get its food?
8. Which makes the nicest gift to send a friend: candy, cigarettes, or flowers?
9. What is it that man and the bacteria, and practically no other organisms, can do—(although nearly all other organisms depend on man or the bacteria to do it for them)?
10. On what chemical magicians are we dependent if we live well? What do they do for us?

CHAPTER XVI

PROTOPLASM

The growth of the organism, from its single-celled beginning, depends of course upon more than a multiplication of cells. It must include an increase in the amount of living stuff, of the *protoplasm*, as we have called it, of the creature.

In order to understand how the amount of a creature's protoplasm can be increased, let us study this living stuff in some detail.

Protoplasm and Life

We have already said that all the living parts of all plants and animals are made of protoplasm.

All protoplasm appears very much alike, whether it occurs in a daisy plant, a mosquito, a human being, or some other organism. When examined closely by means of a microscope, all protoplasm appears colorless or grayish, and seems jelly-like. Whenever it does seem to be colored, as in green plants, the coloring is really a separate thing and not truly a part of the protoplasm.

There is no protoplasm that is not alive. Protoplasm may produce things that are not alive, like the older bones, the feathers, the hair, and the finger-nails of an animal, and the heartwood and the bark of a tree. But such structures are not protoplasm, but the dead products of protoplasm. When protoplasm dies, it immediately changes and becomes something other than protoplasm.

What is there about protoplasm that makes it alive? Perhaps we can answer that question if we examine its chemical composition. Let us see.

Chemical Composition

But if we try to examine protoplasm as a chemist would in his laboratory, we find that we immediately kill it. No way is known to avoid this, and consequently nobody is sure of the composition of living stuff.

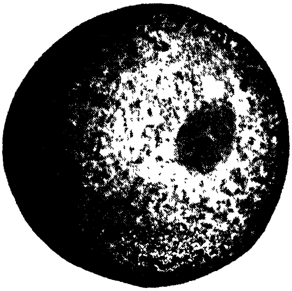

FIG. 163. — PROTOPLASM IN A LIVING CELL

A Mixture of Compounds in Water.—As nearly as we can tell, protoplasm is a kind of combination of solid materials with water. It always contains more water than solid stuff. An animal's muscles may have 75 per cent of their mass made up of water. Jelly-fish are about 99 per cent water. Succulent plants like lettuce and cacti may contain almost as high a percentage. Do you understand how anything with so much water in it can be as solid as your skin and muscles? Protoplasm, you see, is really a sort of jelly, quite like the gelatin pudding which becomes fairly solid even though it is made mostly of water.

The solid stuff in protoplasm is not a single thing, but a mixture of several chemical compounds. A *compound* is a material that contains two or more simpler things. The chemists call such simpler things *elements*. Water, for instance, is a compound of the elements hydrogen and oxygen. Elements are pure materials that contain nothing but bits or *atoms*, as we say, of themselves.

A dozen or more of the chemical elements may be present in protoplasm, but only four of them are abundant. They are carbon, hydrogen, oxygen, and nitrogen, C, H, O, and N, as the chemist abbreviates these names; and 99 per cent of the solid materials in protoplasm consists of these four things.

Carbon.—Now, the elements C, H, O, and N are among the commonest of all the eighty-odd elements on the earth. Carbon, C, occurs in a more or less pure form as lampblack, as graphite (the lead of a pencil), as coal, as charcoal, and as diamond; and combined with some other elements it forms limestone and marble. It is, therefore, very abundant in dead materials as well as in living organisms. Its presence in the common living things about us is apparent from the fact that whenever plant or animal material is partially burned—a piece of wood, toast, or overcooked meat, for instance—charcoal, which is a form of carbon, is left behind.

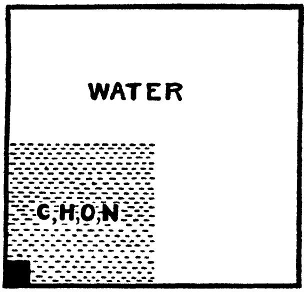

FIG. 164.—COMPOSITION OF PROTOPLASM

But in each bit, these materials are as thoroughly mixed as in a jelly. The black square represents the iron, sulphur, and other elements besides C, H, O, and N.

Hydrogen, H, is a colorless gas, but it is seldom found except in combination with other elements. Combined with oxygen, hydrogen forms the familiar substance water, as the symbols H_2O indicate.

Oxygen, O, is the gas which makes up about 20 per cent of the air; it is one of the two elements in water, and occurs in a very large number of other things on this earth.

Nitrogen, N, is the gas which makes up nearly the whole of the remaining 80 per cent of the air; and combined with hydrogen it forms ammonia.

C, H, O, and N occur, you see, in the commonest of dead things. There are many substances without life that have even all four of these elements combined in them. The mere fact that they occur in protoplasm cannot be the reason why that stuff is alive.

Complex Compounds.—But protoplasm differs from all dead things in the extremely complicated way in which its elements are combined. For comparison, consider water, which we said was H_2O, a compound of two atoms of hydrogen with one atom of oxygen. In contrast, consider that the chemical analysis of a certain one of the many substances in protoplasm indicated that it was $C_{712}\ H_{1130}\ N_{214}\ O_{245}\ Fe\ S_2$. There were 712 atoms of carbon for each 1,130 of hydrogen, 245 of oxygen, 214 of nitrogen, one of iron, and two of sulphur. Had the proportions in that material been only slightly changed, had the proportion of carbon, for instance, been changed from 712 to 711, it might have made a different kind of material.

It is apparent that there are many chances for changes to occur in the complicated chemical structure of a protoplasm. That may be one of the reasons why there are so many different kinds of protoplasm.

Kinds of Protoplasm

How many kinds of protoplasm are there?

Probably there is an infinite number. Probably each has its own peculiar way of growing and of working. We are not altogether certain of this, but everything indicates that protoplasm is not one kind, but an infinite number of kinds of things.

There seem to be as many different kinds of protoplasm as there are different kinds of plants and animals in the world. The protoplasm of a cat is not the same as the protoplasm of a dog. That is why a cat looks different and behaves differently from a dog.

But the differences may go further than that. The protoplasm in the muscles of a cat is probably not the same as the protoplasm in the nerves or the blood or any other part of the cat. Each of the tissues of an organism is probably made of a distinct kind of protoplasm, and that may be why each works in its own distinctive way.

Finally, the protoplasm of any part of a cat at any one time is not exactly the same as the protoplasm in the same part of the animal at a later time in its life. For protoplasm is forever changing.

Think of the infinite kinds of protoplasm there must be!

The surprising thing about it is that all of these different things are so much alike that they can be called by one name, protoplasm.

All kinds of protoplasm are similar in containing large amounts of water, complicated compounds of C, H, O, and N, and the quality which we call life.

Qualities of Protoplasm

Definite Form and Structure.—Living creatures, built of protoplasm, have very definite forms and structures. A rose, for instance, has a very special shape and size and structure. One can usually distinguish a living rose from a dead one by examining it. A dead rose quickly wilts, fades, shrivels, and becomes indefinite in form. Although a wax rose may resemble a living flower in general outline, its finer structure is never so perfect as that of the living thing. Only things made of protoplasm have such definite forms and structures, such remarkably built organs and tissues and cells, as we have found among plants and animals.

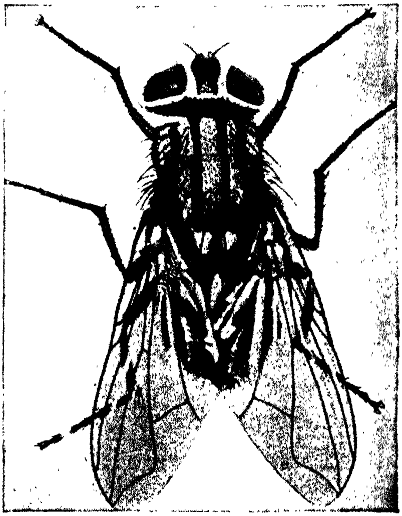
Courtesy U. S. Bur. Entomology

FIG. 165.—THE DEFINITE FORM AND STRUCTURE OF AN ORGANISM

Growth.—Protoplasm can grow by having food materials added to it. Dead things do not grow. One may add cement to a wall, and the height of the wall will increase, but it is not proper to say that the wall has grown. It has merely been added to. The new part is still distinct from the old. Living stuff, on the other hand, actually increases in size. It can take foods and so completely change them that they become more living stuff, indistinguishable from the older protoplasm. This happens every time a plant or animal grows or repairs its worn-out tissues. Only protoplasm is capable of such growth.

Reproduction.—Living structures are able to reproduce and give rise to new living structures, as we have already seen. A wound in an animal's skin is replaced by new tissue which grows out of the surrounding skin. All kinds of protoplasm are capable of reproducing, though, of course, only special kinds of protoplasm, such as egg and sperm protoplasm, can ordinarily grow into complete, new creatures. True reproduction is found only among living things.

Courtesy U. S. Bur. Animal Industry

FIG. 166.—LIVING THINGS MAY GROW

Sensitivity.—A fourth peculiarity of protoplasm is its sensitivity, by which we mean its ability to be affected by *stimuli*—by the things which it meets. A bright light so affects the protoplasm of my eye that I blink. A light may affect the protoplasm of a moth in such a way as to cause it to fly violently into the flame. Sounds affect the protoplasm of my ears. Objects that touch me can be felt. We are sensitive to any number of the things that are about us.

Most dead materials are sensitive only to considerable forces. It may require a hammer to work serious changes on the furniture, the china, or the window pane; but such slight forces as sounds and lights and odors may work great changes on living things. They may cause them to withdraw from the neighborhood, to run away, to go toward the attraction, to talk back to it, to eat it, to think about it, or to do any of a thousand other things. The sensitivity of even the simplest creature is greater than that of any dead thing.

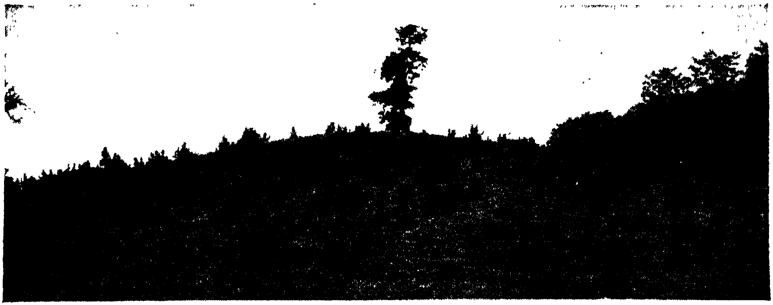

Photo by E. S. Shipp. Courtesy U. S. Forest Service

FIG. 167.—REPRODUCTION: SEEDLINGS FROM A SINGLE MOTHER TREE

Life.— These are the qualities of protoplasm. Are they the reasons why protoplasm is alive? Or is life a separate thing added to protoplasm? If a man should discover how to make the chemical combination of a particular protoplasm, and to manufacture a thing that would have the form and the structure of a living creature, that could grow and reproduce, and that was sensitive, would it be alive?

Perhaps it would!

Perhaps it wouldn't!

SUMMARY

1. All living parts of plants and animals are made of protoplasm. There is no living material except protoplasm. All protoplasm is alive.
2. Protoplasm is much the same thing in all plants and animals.
3. It is difficult to find out the chemical composition of protoplasm, for when we examine it in the chemistry laboratory we kill it, and then it is no longer protoplasm.

4. Protoplasm is a mixture of solid materials with considerable water. The solid materials consist of compounds chiefly of carbon, hydrogen, oxygen, and nitrogen. Other elements may also be present.

5. The proportions in which these elements are combined are much more complicated than in any non-living material.

6. There are as many kinds of protoplasm as there are species of plants, animals, or other organisms; and as many kinds as there are different kinds of tissues in each species. Each protoplasm is, moreover, forever changing!

7. Living creatures built of protoplasm have very definite forms and structures.

8. Living structures built of protoplasm can grow.

9. Living structures can reproduce.

10. Living structures are usually quite sensitive to stimuli (light, heat, sounds, touch, etc.)

11. These four qualities of living things are not combined in any non-living thing.

12. Although we know a good deal about protoplasm, and although we know that it is the only living thing, we cannot tell what it is that we call life.

DEFINE

Protoplasm
Compound (chemical)
Element
Atom
Carbon
Hydrogen
Oxygen
Nitrogen
Growth
Sensitivity

PROBLEMS

1. By what simple experiment could you determine the amount of water in a plant?

2. In how many ways does a wax rose, even a very fine one, differ from a live rose? Make a list of them.

3. Make a list of plant and animal materials (such as watermelons, lettuce, hen's eggs) which you think must contain a large percentage of water.

4. Make a list of plant and animal materials which you think must have little water in them.

5. Make a list of dead products of protoplasm (such as bark, finger-nails, hair, etc.).

6. In what way is the production of new skin over a wound like the division of a protozoon and like the reproduction of a higher plant and animal? What are the most important differences?

CHAPTER XVII

BUILDING FOODS AND PROTOPLASM

Organisms, then, grow by adding food materials to their protoplasm. Growth of any part of a living structure, and the repair of worn-out and damaged structures, is accomplished by the transformation of dead food materials into new living structures.

All of those changes which go on in an organism in the course of its growth and other activities, are known as processes of *metabolism*. The processes by which foods are manufactured, and by which they are turned into protoplasm, are known as processes of *constructive metabolism*.[1] Later we shall study the processes of destructive metabolism, in which foods and protoplasm are destroyed for the sake of obtaining the energy which they contain.

Classes of Foods.—Since protoplasm is largely a mixture of compounds of C, H, O, and N, the chief foods of plants and animals must be made mostly of the same chemical elements, C, H, O, and N. Any compound or mixture of compounds of C, H, O, and N, which can be used to build protoplasm or to supply the energy that an organism needs to do work, is called a *food*. As often as you have eaten things, have you ever stopped to realize why certain materials are and others are not foods?

There are only four classes of foods, namely carbohydrates (starches and sugars), fats, proteins, and mineral foods. The carbohydrates and fats contain the C, H, and O that the protoplasm needs, while the proteins contain all four of the elements, C, H, O, and N. The mineral foods supply the iron, calcium, sulphur, and still other elements that enter into protoplasm.

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[1] Also known as *anabolism*.

Carbohydrates and Photosynthesis

The two chief groups of carbohydrates are starches and sugars.

Animals get their carbohydrates from the plants which they eat. They find starches in more solid vegetables like beans, potatoes, turnips, rice, oatmeal, and wheat (bread). They get sugar carbohydrates from almost every vegetable and fruit, and the manufactured sugar which we use in our homes similarly comes from plants (sugar cane or the roots of beets).

But, now, where do the plants get their carbohydrates?

We have already said that plants manufacture their starch and sugar foods. That is something that animals cannot do. Plants manufacture starches and sugars, C,H,O compounds, out of carbon dioxide (CO_2) and water (H_2O).

The Raw Materials.—Carbon dioxide is a gas found in the air, it is produced by the burning of wood and of coal, it develops wherever there is decay, and it is one of the waste products of breathing among both plants and animals. It is carbon dioxide which causes the bubbles in soda water. This gas and the familiar substance, water, are the materials used by plants in this food manufacturing. It is a very remarkable performance!

Light is Necessary.—This whole process is called photosynthesis, meaning light manufacturing, because it can take place only in sunlight. Plants do not manufacture carbohydrates at night. Cloudy weather slows up the process, and plants grow only slowly then. If a plant is put in a dark place, as in a cellar, it will live for a while on what food it may have stored up in its roots or in a bulb, but it will soon lose its green color and may die, starved to death because it cannot manufacture its food without sunlight. Sunlight appears to supply the energy necessary for turning the wheels, as it were, of the photosynthesis factory. That energy is stored up in the food as it is manufactured, and the organism that later uses the food finds the energy in it. After an animal has eaten a carbohydrate food it may have energy enough to move or to keep warm. Practically all of the energy used by plants and animals is thus derived from that distant but very important sun of ours. Little Johnny Jones, you see, really throws his ball with preserved sunshine!

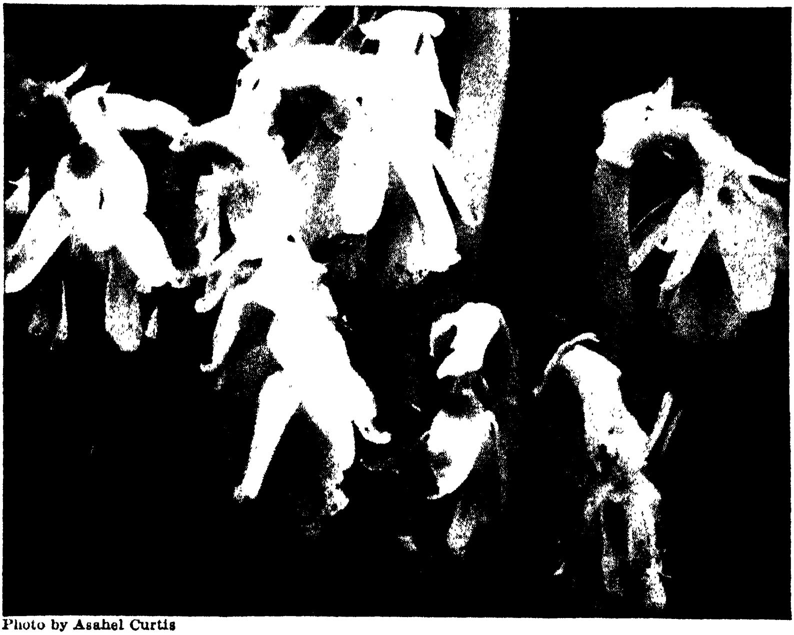
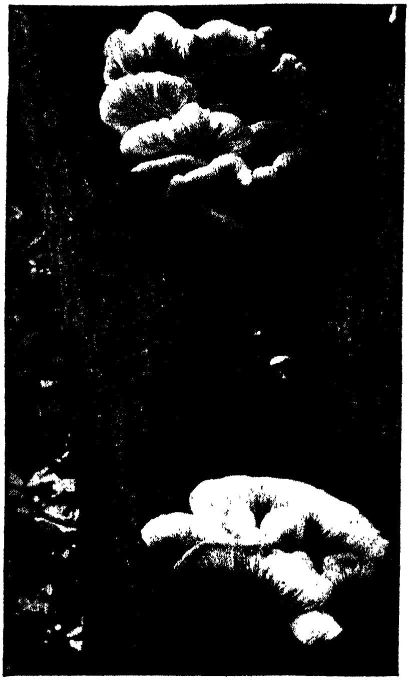


Photo by Asahel Curtis

FIG. 168.—INDIAN PIPE
A flowering plant lacking chlorophyll.

In Green Leaves.—Even with sunshine, photosynthesis cannot occur in a plant unless the green material, chlorophyll, is present. We are not quite certain what chlorophyll has to do with photosynthesis, but it appears to be absolutely necessary. Plants that lack it, things like the Indian pipe and the toadstools, have to live as thieves or scavengers that get their carbohydrates from other organisms. If the leaves are taken off a green plant, the plant will stop growing and perhaps die, because it can no longer manufacture its own carbohydrates.

Sugar Produced.—A sugar of one sort or another is the carbohydrate which is manufactured in photosynthesis. It may be stored in the plant as a sugar (this is so in fruits and in sap), or it may be turned into a starch (as in the potato and in cereal grains). The change from a sugar to a starch, and from a starch to a sugar, is easily accomplished. You will realize this if you will recall that a grain of wheat, when first chewed, is almost tasteless because of the starch in it, but that it soon becomes sweet when the starch in it is turned to sugar by the saliva in your mouth.



Courtesy U. S. Bur. Plant Industry

FIG. 169.—A FUNGUS PARASITE
Taking its food from a linden tree.

Oxygen Produced.—Pure oxygen is manufactured at the same time as the carbohydrate. The gas passes out of the plant into the air. Thus a supply of oxygen is provided for both plants and animals. The oxygen given out in photosynthesis should not be confused with the carbon dioxide which is given out when plants (as well as animals) breathe. In the daytime, when photosynthesis is most active, plants may develop a dozen times more oxygen by photosynthesis than carbon dioxide by breathing; but at night, when photosynthesis has stopped, the carbon dioxide breathed out is the only gas produced.

Thus photosynthesis is a tremendously important process to both plants and animals. It is the only source of carbohydrates, and it takes carbon dioxide out of the atmosphere and returns pure oxygen. Don't you think everyone should know something about a process upon which we are so dependent for our existence?

Fats

Fats are also C,H,O compounds. They are manufactured in both plants and animals. Most organisms easily change carbohydrates into fats. In addition to this, the human obtains many fats directly from butter, milk, fat meats, eggs, nuts, and such plant oils as substitute butters, salad oils, etc.

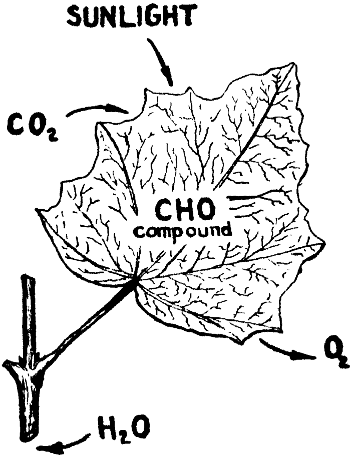


FIG. 170.—PHOTOSYNTHESIS

Can you explain this diagram?

Proteins

Proteins are complicated compounds of all four of the elements, C, H, O, and N.

Most plants are able to manufacture proteins out of certain complex nitrogen compounds, and animals secure their proteins second-hand from their food plants or from the other animals which they eat. In the human diet proteins are found chiefly in meats, milk, and grains (as in bread), in a few seed vegetables such as navy beans, lentils, and peanuts, and in many true nuts.

Building Nitrogen Compounds.—But there are certain organisms which are able to build up proteins from very simple

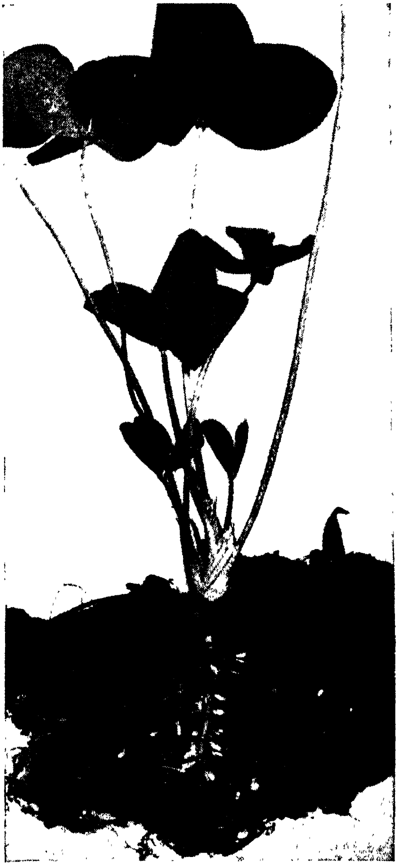
N compounds or from pure N itself. These are certain of those simple organisms which we call bacteria. It is possible that some of the blue-green algæ are also able to manufacture nitrogen compounds beginning with pure nitrogen; but we know more about the importance of the bacteria as the sources of proteins.

Sometimes bacteria begin with very simple nitrogen compounds, and from them manufacture the complicated protein compounds. The simple nitrogen compounds with which they begin are to be found in solutions in the soil, in fertilizers, and in decaying plant and animal materials. Ammonia, NH_3, a combination of nitrogen with hydrogen, is one of the simpler compounds that can be used by bacteria.

FIG. 171.—GREEN PLANTS ARE THE ULTIMATE SOURCES OF OUR FOODS

Using the Nitrogen of the Air.—There are, however, some bacteria that can use pure N. Now, abundant as nitrogen is in the air, constituting nearly 80 per cent of all the air about us, it is an exceedingly difficult thing to combine nitrogen with any of the other elements. It was well after 1900 before man discovered how to accomplish this thing; but for ages certain of the bacteria living in small, knotty growths on the roots of certain plants of the pea family (beans, peas, clovers, alfalfa, and others) had been taking N out of the air and combining it with C, H, and O to form compounds which finally became proteins.

Farmers have known for a long time that they should rotate their crops, putting different ones into a field in successive years, and that the rotation should include a clover or some related plant. A little more than a half century ago it was discovered that the clover bore bacteria which could put nitrogen compounds into the soil. Pull up a clover or bean plant next time you meet one; and if it is in loose soil the growths will not be pulled off. Examine them, and have respect for them. If you can break one open and wash it out onto a glass slide under a microscope, you may see the swarming bacteria.



Courtesy U. S. Bur. Plant Industry

FIG. 172.—BACTERIA NODULES
On roots of red clover. Natural size.

The C,H,O part of the C,H,O,N protein is the source of the energy which that protein contains, just as it is with the carbohydrate and fat foods.

Minerals

In addition to the C,H,O,N foods, all organisms require mineral materials, chiefly calcium, iron, sodium, potassium, phosphorus, and sulphur. Some of these help build protoplasm and are, therefore, true foods; while others merely aid in metabolism without actually entering into the composition of the protoplasm.

Soil materials, especially fertilizers, furnish these minerals for plants. Vegetables, fruits, and common salt supply the minerals to animals.

Some of the minerals are very important things in a diet. For instance, calcium, to be obtained from milk and from leafy vegetables, aids in the formation of the bones of higher animals. Iodin helps prevent improper functioning of the thyroid glands. Diseases of the thyroid are common in parts of the Middle West and in other countries of the world where, it would appear, there is not enough of the mineral in the drinking water and in the soils in which food plants are grown to supply the needs of the human.

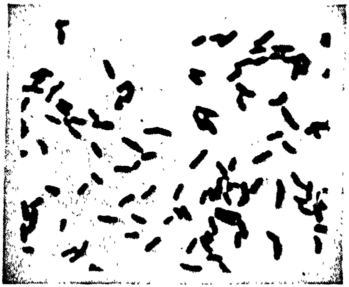

Courtesy U. S. Bur. Plant Industry.

FIG. 173. — NITROGEN-FIXING BACTERIA

On roots of a legume. Magnified 2,000 times.

Digestion and Assimilation

Digestion.—A great series of chemical changes usually has to occur before foods become protoplasm, or before they can furnish energy to an organism that has eaten them. Many of the things we swallow contain materials that are not foods at all, and such stuff must be separated and cast out as wastes. For instance, the only real food in a piece of fruit is a small quantity of sugar and minerals, and the bulk of the fruit is

15. What kinds of materials are lacking in the "run-down" or "worn-out" soil of an old farm?

16. Have you had your variety of vitamins today? Yesterday? The day before? Prove it.

17. Can you explain why scurvy is now less common on ocean vessels and more common on land than it was a hundred years ago? Why is it now more common in cities than in suburban and farm districts?

18. What are the advantages and disadvantages of pasteurized milk compared with raw milk?

19. Why are wood ashes so valuable as a garden fertilizer?

20. What are the chances of securing vitamin C by eating tomatoes which are: (a) freshly cooked at home from fresh fruit bought in the market; (b) a good brand of canned tomatoes slightly warmed up immediately after opening; (c) fresh fruit eaten raw; (d) canned tomato juice served without cooking; (e) canned tomatoes thoroughly cooked after opening?

21. Swiss mountain climbers often carry milk chocolate as an emergency food. Discuss its merits and faults as a balanced ration.

22. In 1870 the German army used an emergency ration (Erbswurst) consisting of a dry soup preparation made chiefly from fat pork and peas. Discuss its merits and faults as a balanced ration.

23. On the Fremont Expedition to the Sierra Nevada (1849) the food supplies on which they depended were coffee, sugar, flour, tallow, and dried peas. Sometimes this ration was supplemented with meat from animals they killed. Discuss this as a balanced ration.

24. Mountain climbers in this country carry an emergency ration of sweet chocolate (not milk chocolate), salted peanuts, and raisins. Discuss this as a balanced ration.

25. Recommend the best emergency ration you can devise which will have, as far as possible, the following qualities: compactness, minimum weight, ease of preservation and transportation, maximum amount of nourishment, a balanced portion of each class of the foods, and necessary vitamins.

26. Carbohydrates are manufactured in plants usually as sugars, but stored as starches. What advantages do you see in that?

27. In making a humus pile as a source of garden fertilizer (see p. 79), it is good practise to mix into it a chemical fertilizer that contains a good deal of nitrogen. What good does that do?

28. How does a hair-covered, plant-feeding mammal that lives underground—a mouse or a mole, for instance—avoid having rickets?

CHAPTER XVIII

USING FOODS AND PROTOPLASM

Protoplasm is forever changing, going to pieces chemically and dying, even though the plant or animal in which it occurs may keep on living. Do you see how this can be so?

It is like the river—the stream which flows down there in the pasture—that goes on from day to day. It is the same stream all of the time, and yet it is not the same, for you know that its water is continually flowing away.

So with protoplasm. It is continually wearing away, breaking down, becoming old, and dying. These things are to be expected.

But changes also occur because there is energy, *an ability to do work,* stored up in protoplasm, and because that energy cannot be got out and set to work until the living material is destroyed and chemically broken down. It is only by using this released energy that a plant or animal is able to move, to keep warm, to work. An organism whose protoplasm is not continually changing and continually dying is already a dead organism.

The break-down of protoplasm, together with the break-down of foods to secure energy directly, is known as *destructive metabolism.*[1]

Destructive Metabolism

The four ways in which destructive metabolism may be accomplished are these: respiration, fermentation, waste, and decay.

Respiration.—Of these, respiration, or breathing, is the principal way in which energy is released in most organisms.

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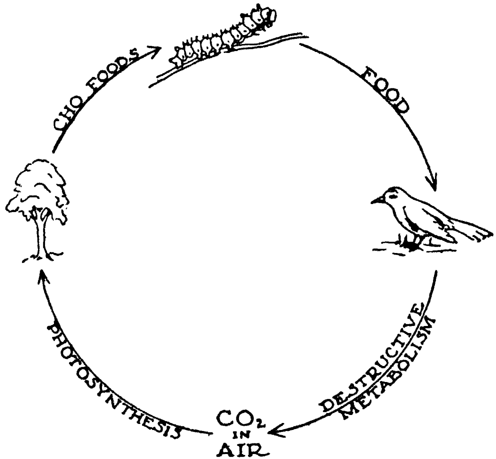
[1] Also called ***katabolism.***

You are familiar with the fact that an animal has to keep breathing in order to remain alive, but have you realized what the process accomplishes, and do you know that plants are similarly respiring?

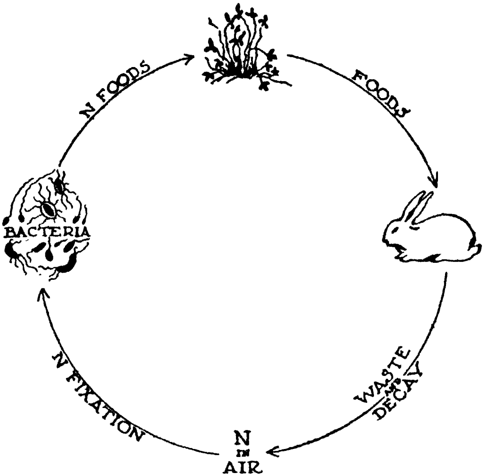
In respiration the organism takes in oxygen, O, the foods and protoplasm (C,H,O and C,H,O,N compounds) are broken down (in some way which we apparently do not understand so well as we thought we did a few years ago), and CO_2, H_2O, and energy are released. This is true of both plants and animals. Do not confuse the CO_2 produced by respiration in a plant with the O produced by photosynthesis. Oxygen is taken in, not given out in respiration. The CO_2 gas resulting from respiration, and the water vapor are breathed out, while energy is produced in forms which we shall consider later.



M. L. Voorhees, Del.

FIG. 178.—THE CARBON CYCLE
Can you explain this diagram?

Fermentation.—Yeasts, which are very simple fungus plants lacking chlorophyll, and certain bacteria are able to break down sugars (C,H,O compounds) without first taking in oxygen. This process is fermentation. It is not so different from respiration, and it replaces the process of respiration in the organisms in which it occurs. It differs from respiration chiefly in occurring without the presence of oxygen. Moreover, only certain kinds of sugars can be fermented. The products of this break-down are CO_2, grain alcohol (a C,H,O compound), and energy. The grain alcohol which is used for liquors, preservatives, fuel, and other purposes may be obtained from the fermentation of grains and sawdust by bacteria and yeasts. For another purpose, the yeast plants may be bought in compressed cakes; fermentation occurs when they are put into a moist and warm place, and the resulting CO_2 gas may be used, for instance, to raise our baking breads.



M. L. Voorhees, Del.

FIG. 179.—THE NITROGEN CYCLE

Explain this diagram.

Waste.—Foods and protoplasm may go to pieces chemically because of complicated processes which we call *waste*. In such a case the protoplasm dies. Most of the live parts of an organism thus waste away, bit by bit. Sweat and urine, containing nitrogen compounds, are familiar waste products in the higher animals. In the end the process produces CO_2, H_2O, a variety of N compounds, and energy. Waste, you see, differs from respiration in producing the N compounds. A horse stall may smell strongly of such a compound, ammonia, which is a simple N compound found in the urine of the horse.

Decay.—In processes of decay bacteria of certain sorts—again it is bacteria!—destroy protoplasm, foods, and the waste and dead materials of plants and animals. CO_2, H_2O, N compounds, pure N, and energy are produced. Pure N is released in decay as in none of the other processes of destructive metabolism. Unfortunately the energy released in decay usually escapes, but there is considerable energy released. A manure heap, the inside of a straw stack, or the interior of the mound nest which the ants have built are all considerably warmer than the surrounding air—because of the heat energy released by the decay that is going on in those places.

Energy Released

The energy released in destructive metabolism is turned by organisms into motion, heat, light, and electricity.

It is a common thing for one kind of energy to be turned into another. For instance, coal, when it is burned, gives out heat energy; this makes the steam used to produce movement in a dynamo; the motion of the dynamo is transformed into electric energy; this electricity may produce light in your home; and at the same time the electric bulb releases a quantity of heat energy. This is one of the everyday instances of the transformation of energy.

It is in a similar fashion that the sun's energy entered into the foods and the protoplasm; and now, in destructive metabolism, it is changed into heat, motion, light, and electricity. Organisms never make these energies, but they do release them from their foods and protoplasm every time they respire, cause fermentation, waste, or decay.

Heat.—This is one of the most familiar of the energies released by metabolism. All the higher animals produce considerable heat. The so-called "cold-blooded" animals, like the frogs, snakes, fish, and insects, do produce some heat, although it is not enough to keep their bodies much above the temperature of the air. Plants develop still less heat, but there is probably some produced in all of them. When a plant's metabolism is hastened, as during the rapid opening of flowers like the Jack-in-the-pulpit and the calla lily, the rise in temperature may be shown on a thermometer to be two or three degrees; and in some flowers of the tropics, as much as eight degrees.

Motion is another familiar result of metabolism. It is hard for us to think of an animal that could not move muscles, walk, run, jump, fly, or swim. Plants usually move very

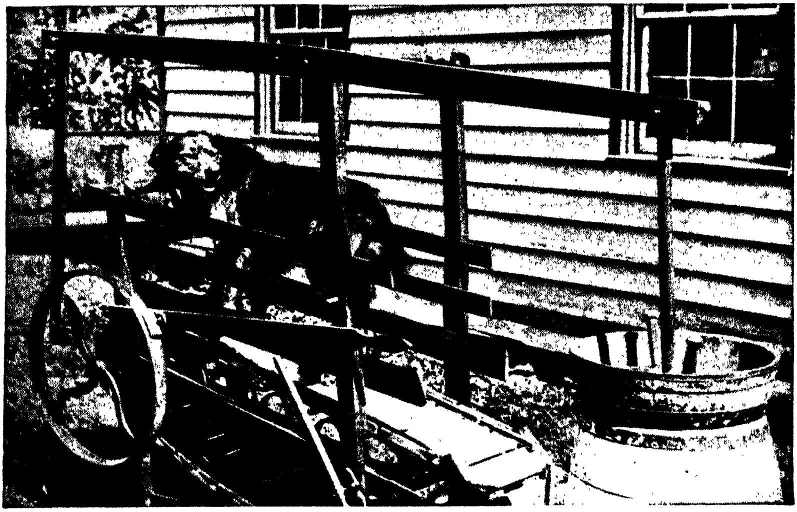
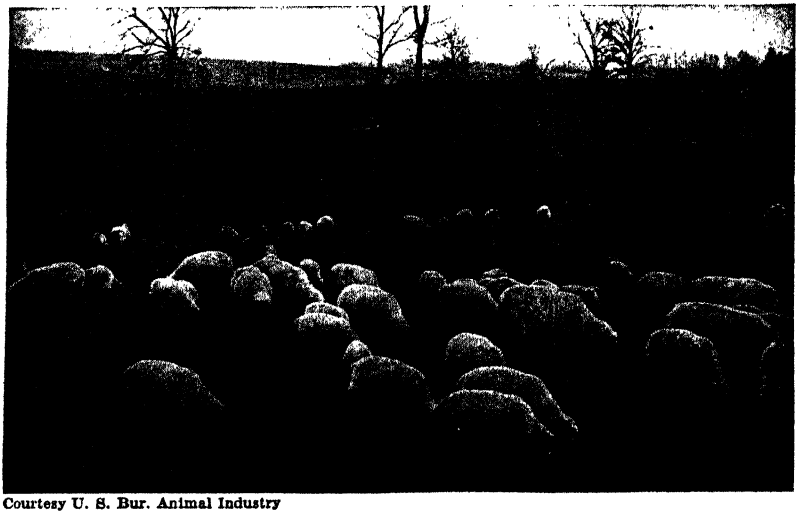


FIG. 180.—THE TRANSFORMATION OF ENERGY

Can you show that energy from the sun is running the churn, and that there is energy from the sun in the butter that is being made?

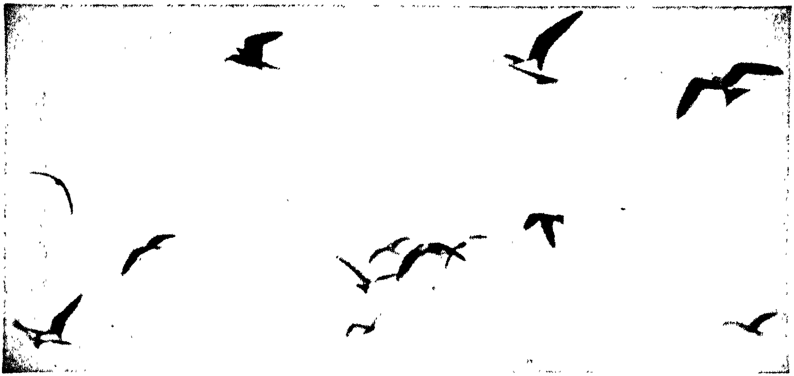


Courtesy U. S. Bur. Animal Industry

FIG. 181.—A WOOL COAT IS WARM

Because it retains the heat released in the animal's destructive metabolism.

slowly, but they change the positions of their leaves and stems, partly by movements of their protoplasm, partly by growing in one direction. The sunflower is not the only example of a plant that changes position as the sun circles across the heavens; you may find many common field and garden flowers that similarly move. The movements which open many spring flowers, such as crocuses and tulips, can readily be seen an hour or two after sunrise. The sensitive plant and the Venus fly-trap close their leaves when touched, the latter thereby capturing insects that serve as food.



Courtesy P. Bartsch and Smithsonian Inst.

FIG. 182.—MOTION
The result of destructive metabolism.

The so-called sleep movements of the leaves of many plants occur after sun-down and reverse at sun-rise. There is nothing in this action that should be compared to the real sleep of animals. The changes are mostly due to changes in temperature. As a result of the movements, cold dew is prevented from settling on the surfaces of the leaves. Take a lantern or flashlight some summer night and hunt for the common plants of your region. If it is cool enough you may have difficulty in recognizing them. Examine the things shown in the illustrations. They will surprise you if you have never before seen them after dark. Almost all flowering plants show some sort of sleep movement; but those with compound leaves (made up of more than one leaflet) are the most interesting, and these include clovers, alfalfa, locusts, acacias, walnut, butternut, wood sorrels, roses, blackberries, and sumacs.

Electricity.—Organisms do not often produce electricity in quantities large enough to be noticed, although most of them probably develop some energy of this sort. Some of the North American rays and the South American electric eels, both of which are fish, defend themselves with electric shocks strong enough to injure a man or a horse.

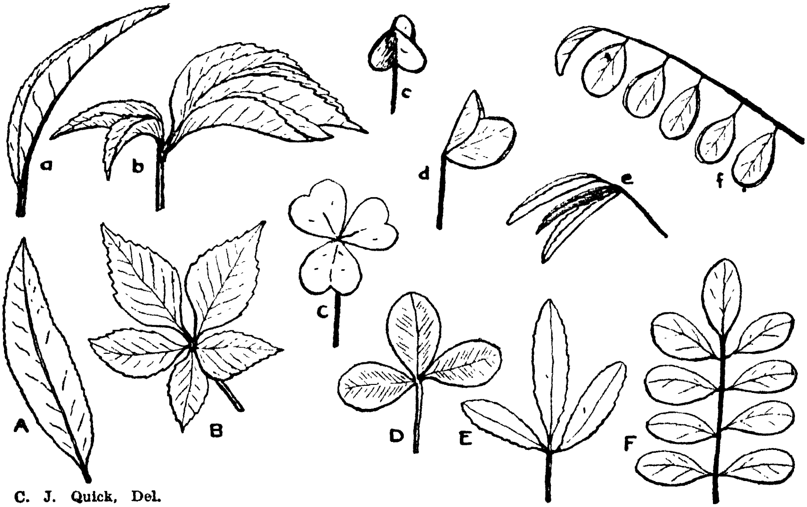
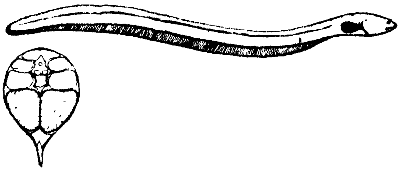


FIG. 183.—PLANT SLEEP MOVEMENTS

Showing daytime positions (lower figures) and night positions (upper figures) of A, peach; B, Virginia creeper; C, wood sorrel; D, Alsike clover; E, sweet clover; and F, locust tree.

Nervous Energy.—Another energy seems to occur only among animals. The sensations of seeing, hearing, feeling, smelling, touching, feeling pain, feeling hot or cold, and feeling movement, as well as all thought, are results of nervous energy released in the destructive metabolism of protoplasm.

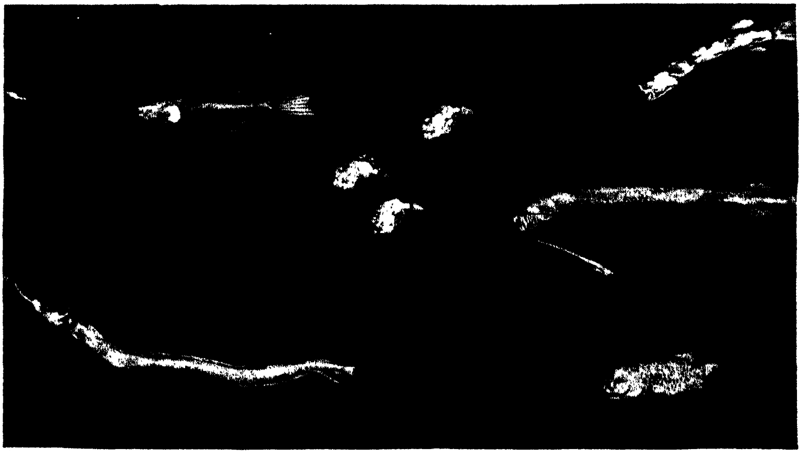
Light.—Among the organisms that produce light energy, the fireflies (certain forms of which are known as glow-worms) are the most familiar. Their lights are remarkable in being nearly 100 per cent efficient, little of their energy going into the production of heat. The best electric light on the market is only 3 per cent efficient, most of the energy being lost in heat. A fortune awaits the man who can successfully and commercially duplicate the firefly's light. Similar light is produced by a few other insects. In the depths of the sea the prevailing darkness is broken by lights produced by some of the fish. These fish lights show continuously, or flash occasionally; sometimes they occur in patches along the sides of the body, sometimes at the tip of a long process held like a lantern in front of the animal's head.



C. J. Quick, Del.

FIG. 184.—SOUTH AMERICAN ELECTRIC EEL

In the cross-section of the eel's body, the muscle which releases the electricity is shaded.



Courtesy Amer. Mus. Nat. Hist.

FIG. 185.—LIGHT PRODUCTION IN DEEP-SEA FISH

There are also myriads of smaller organisms, small jellyfish, worms, microscopic animals, and many bacteria which produce light. Bacteria living in decaying logs and other moist places produce "fox-fire." I have seen whole stands of decaying stumps giving out light enough for reading a newspaper. The microscopic, light-producing animals are sometimes so abundant in a sea that on a dark night every disturbance of the water is illuminated, every ripple is a band of dim and greenish light, every breaking wave is a brilliant shower, every drop from the oar becomes a flashing gem. Some day you should go to the ocean and stay until you can see such a "phosphorescent sea."

Courtesy U. S. Bur. Agric. Economics

FIG. 186.—PLANTS STORE ENERGY WHICH ANIMALS MAY USE

Rate of Metabolism

The amount of energy released in any organism is naturally related to the rate of its destructive metabolism. If an animal is to increase the rate of its movement, its respiration must increase in volume or become more rapid than usual. Birds, in order to maintain their high blood temperatures and to fly as rapidly as they do, have to metabolate very rapidly. The next time you see a swallow or a chimney swift in flight, think of the metabolism going on in its body. The growing boy gets around faster than his grandfather, partly because in youth he is able to metabolate faster than in old age. One may have that much-admired quality, "pep," only when he possesses a more rapid metabolism. Snakes are sluggish animals, for they metabolate slowly.

The faster the rate of destructive metabolism, the greater the amounts of food needed to repair the damage. The active youth mentioned above just has to have a disgracefully large appetite. Birds need to feed continuously while awake, but snakes need a meal only about once a week or so.

Plants have low rates of destructive metabolism, but they have high rates of constructive metabolism, and so they store up more food and energy than they ever use. Animals reverse the process, and they have to depend upon plant foods for their energy.

Secretions

While destroying protoplasm and transforming energies, destructive metabolism also produces many kinds of secretions. These are peculiar chemical substances with remarkable powers.

Certain of these secretions, called *enzymes,* are produced in such small amounts that we know little about them although we are well acquainted with the work they do. It is an enzyme in animal saliva that turns starches into sugars. Another enzyme, pepsin, digests proteins in both plants and animals.

Glandular secretions are produced in special parts of plants and animals called glands. Glands in animals produce saliva, sweat, tears, milk, the poisons of snakes and of insects, the wax of bees, the silk of caterpillars, the shells around birds' eggs; the shells of snails, clams, lobsters, and insects, the glue with which a wasp transforms chewed wood fiber into paper for its nest, most of the animal digestive juices, and a very long list of other things. Glands in plants produce clove oil, cedar oil, orange and lemon oils, the odors of flowers and many strongly scented leaves, and the bitter tastes of other leaves and stems. Plant cells may also produce resin, camphor, morphine, nicotine, the colors of flowers and of leaves, other tasty things in spices, etc.

The gland of simplest structure is merely a single cell containing a liquid secretion in addition to its protoplasm. This secretion pours out of the cell when needed. The glands of animals are more often clusters of such cells arranged like the lining of a bottle, and pouring their secretions into the central cavities. The familiar salivary glands have such a structure.

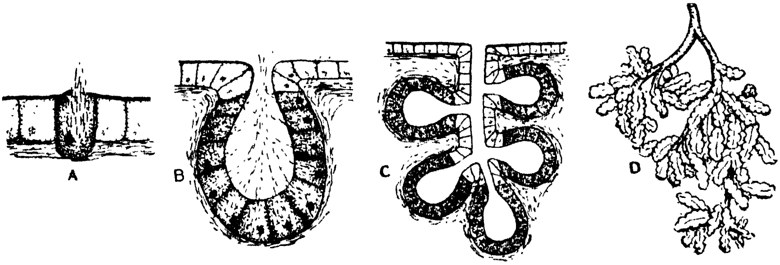


FIG. 187.—SIMPLE AND COMPLEX GLANDS
Secreting cells, A-C, are shaded. Part of a more complex gland in D less highly magnified.

Ductless Glands

Among the most important glands of higher animals are the ductless glands.[1] There are no central ducts through which the secretions can be poured out of these glands, but the secretions go directly into the animal's blood, and are thus distributed all over its body. The important materials in these secretions are called *hormones*. These hormones have such tremendous powers that sometimes an overdose or underdose of an infinitely small amount may cause serious disorders throughout the body of the animal.

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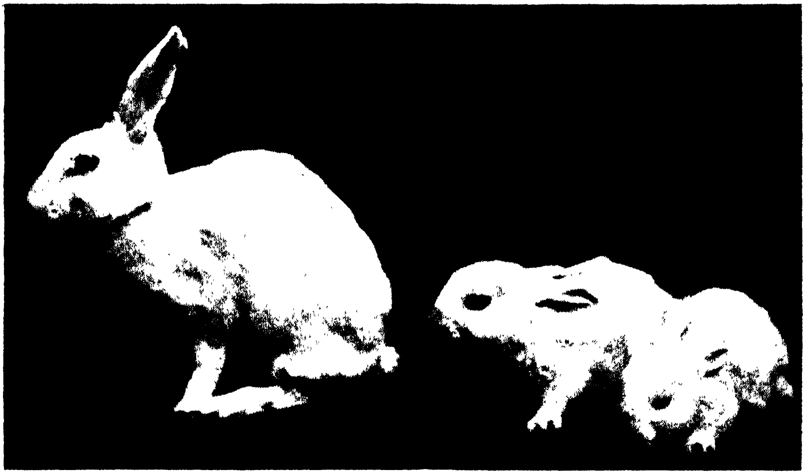
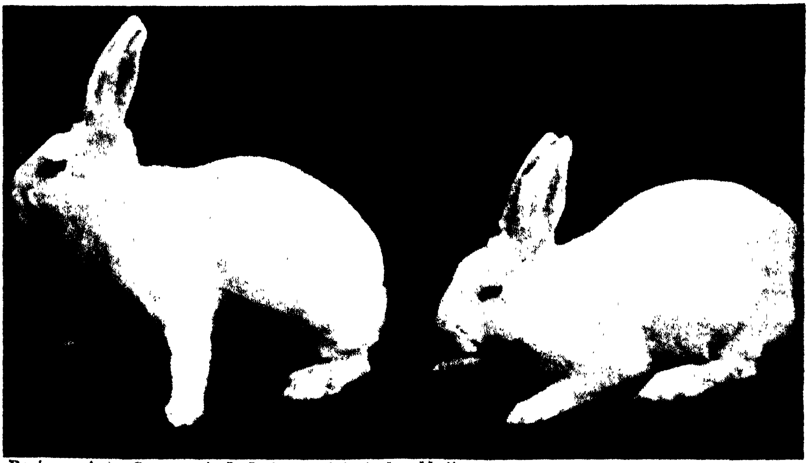
[1] Also called *endocrine glands*, or *glands of internal secretion*.



Basinger photo. Courtesy A. J. Carlson and Arch. Int. Medic.

FIG. 188.—THE EFFECT OF THYROID DEFICIENCY
Normal rabbits (left) and abnormal rabbits (right) from the same litter.



Basinger photo. Courtesy A. J. Carlson and Arch. Int. Medic.

FIG. 189.—SAME, AFTER THE ABNORMAL RABBIT (RIGHT) WAS FED THYROID EXTRACT

Thyroid Glands.—Thus, if the thyroid glands in a mammal, located in the upper part of the neck (in front) do not receive enough iodine they do not deliver enough of their secretions. Then the animal becomes much too fat and is sluggish mentally, and a goiter (a neck swelling) may form. In some cases where there is a shortage of iodine a different result follows. This is apparently due to the fact that the hormone produced under these circumstances does not have the normal chemical constitution. In such a case a goiter may develop also, but the individual becomes very thin because its starch and sugar foods are not properly digested, the whole nervous system becomes too active and very unreliable, movements become jerky and uncontrolled, and the whole body is upset.

In cases where there is an overdose of iodine and in consequence an over-supply of the thyroid hormone, the victim is upset in much the same way as though it were suffering from the chemically abnormal hormone, the effects of which have just been described.

A surprisingly large number of people have thyroids that are not properly functioning. A physician may correct some of these troubles by giving iodin or a preparation of the thyroid of sheep. In severe cases it may be necessary to remove part of an over-developed gland.

Diabetes.—The sugar foods that are carried in the blood in a healthy mammal are finally taken up by the various body tissues, or else stored in the liver of the animal. The rate at which this sugar consumption proceeds is determined by a secretion, *insulin* by name, which is produced by ductless glands in the pancreas of the animal. If the supply of insulin fails, too much sugar accumulates in the blood and in the excretory system of the individual, and a very serious condition known as *diabetes* results. This is a rather common disease, and one which physicians were until recently unable to prevent becoming fatal. One of the spectacular triumphs of science has been the recent discovery of a way of securing insulin in a pure form from the pancreas of other mammals. By injecting this drug into the human blood, it is now possible to maintain the life of the diabetic patient at something approaching a normal rate.

Other Ductless Glands.—Similarly other ductless glands must function just properly to prevent disorders. The sex glands (the ovaries and testes of higher animals), in addition to producing eggs and sperm, produce a hormone which controls the sexual instincts and many of the characteristics which distinguish a male from a female animal.

A tiny gland, the pituitary gland, located above the roof of the mouth, has most to do with the limits of growth; and giants and dwarfs are usually extreme results of disorders of this gland.

The sudden pouring out of the hormone from the adrenal glands is responsible for much of the behavior of the frightened or angry individual: his inclination to run, his feeling of anger, his sudden and hard breathing, his unusual strength in the fight that follows, his lack of attention to the wounds he may receive in the conflict, and even for the greater ability of the blood to clot and close up such wounds far more quickly than in the individual who remains calm and unafraid.

Such are some of the remarkable things that living bodies do.

SUMMARY

1. Protoplasm is forever changing and dying. It is by this means, and by this means only, that the energy stored in the protoplasm can be released for the use of the organism.
2. There are four ways in which destructive metabolism is accomplished. Of these, respiration is the principal way. This is true of both plants and animals. The organism takes in oxygen, the foods and protoplasm are broken down, and CO_2, H_2O, and energy are released.
3. Instead of securing their energy through respiration, yeasts and some bacteria secure energy by fermenting sugars. CO_2, H_2O, alcohol, and energy are released.
4. By chemical changes the living protoplasm may waste away. CO_2, H_2O, various N compounds, and energy are released.

5. Certain kinds of bacteria may cause the decay of protoplasm, foods, and other plant and animal materials. CO_2, H_2O, various N compounds, and energy are released.

6. The energy stored in the food or protoplasm came from the sun when the carbohydrate was made by photosynthesis, and was preserved in it when the carbohydrate was turned into fat, or combined with nitrogen compounds to form proteins or protoplasm.

7. Heat is the most familar form in which energy is released by destructive metabolism.

8. Motion in both plants and animals is also the result of destructive metabolism.

9. Electricity, nervous energy, and light are forms of energy released less frequently in destructive metabolism.

10. The faster the rate of destructive metabolism, the greater the amounts of energy released, and the greater the amounts of food needed to repair the damage. Plants store more energy than they use. Animals use more energy than they can store, and consequently depend upon plants as their source of energy.

11. Secretions of many sorts are also produced in plants and animals in the course of destructive metabolism.

12. Among the higher animals, ductless glands produce very small amounts of hormones. These, however, regulate the functioning of all parts of the body with the utmost precision. The hormone of the thyroid glands controls starch digestion, nervous activities, and many other body functions. A hormone (insulin) produced in the pancreas controls the use of sugar by the organism. A hormone secreted by the sex glands controls the secondary sexual characters. A hormone from the pineal gland controls the limits of growth. The adrenal glands control the rate of metabolism.

DEFINE

Energy
Destructive metabolism
Respiration
Fermentation
Carbon cycle
Nitrogen cycle
Waste
Decay
Transformation of energies
Secretion
Gland
Ductless gland
Hormone
Thyroid
Insulin
Diabetes
Pineal gland

PROBLEMS

1. Can you explain why flowers are often removed from sleeping rooms at night? (This custom is correct, but not so important as might seem.)

2. How many simple methods can you give for preventing decay in fruits and vegetables and in meats? Explain how each method accomplishes its purpose.

3. How many kinds of energy have gone into the piece of baked bread that you eat? In what forms can you take the energy out of that bread?

4. Can you show how each of the energies that went into that piece of bread originated in the sun?

5. Can you explain why we do not need to eat so much in warm weather as in cold? What kinds of foods should be included only sparingly in summer menus?

6. Is digestion a process of constructive or destructive metabolism? Be careful of your answer.

7. Explain in detail the carbon cycle shown in Fig. 178.

8. Explain the nitrogen cycle shown in Fig. 179.

9. Make a simple diagram showing the oxygen cycle.

10. Make a simple diagram showing the hydrogen cycle.

11. In addition to the coal-steam-dynamo-light-heat case cited in this chapter, give some other examples of the transformation of energies.

12. Which is the most valuable for fertilizer: fresh manure, older manure that has been kept in a dry shed, or old manure that has been lying in the open? Explain.

13. Look about your home and find at least one case of sleep movements of plants which is not mentioned in this chapter.

14. Make a list of all the organisms which you have ever seen producing light.

15. Explain several methods by which you might keep warm out-of-doors on a cold winter day. Show where the heat energy comes from in each case.

16. In what ways is the supply of carbon dioxide in the air being replenished?

17. Hay stored in a barn will sometimes catch fire by "spontaneous combustion." Would it reduce the danger if the hay were kept slightly damp? Explain.

18. In the above case, would it reduce the fire danger if the hay were sprinkled heavily with salt? Explain.

CHAPTER XIX

HUMAN HEALTH

By the good health of any plant or animal we refer to its ability to perform all of its processes of constructive and destructive metabolism in the most efficient way.

We are, of course, much interested in keeping our own bodies metabolating properly. These human machines are capable of accomplishing so much if they are decently cared for! The big and worth-while things in life are so often done by the folks who are not handicapped by bodily misfortunes!

We shall, therefore, want to give especial attention to that part of animal physiology which is known as hygiene, the science of human health. In this one chapter, we shall not be able to discuss all we should know about hygiene, but we can begin thinking about it.

Food Hygiene

First of all, about foods, we may consider those people who have decided notions as to what they like and will eat, and what they don't like and won't eat. They are not going to get all of the four kinds of foods and the vitamins which we have learned are necessary for the building of good protoplasm. That is too bad, for likes and dislikes of particular foods are largely the results of habits, depending upon what we have become accustomed to eating. Review what you have learned about foods and vitamins, and see the advantages in including a wide range of things in your diet.

Of course, we must watch how we furnish the fuel to these engines of ours. We must avoid overloading them. If we eat too fast, or too much, we shall not be able to digest properly and completely what we have taken.

Regular meal hours, with complete rests from eating in between, give the digestive organs an opportunity to repair damage before further encounters. The habit of continually eating between meals is bad.

Water.—Although water is not a food it is a considerable aid to digestion, and as such it may be taken with our meals, provided we do not drink while we still have food in our mouths. The drinking of water is also a means of washing out the wastes from digestion and destructive metabolism. The kidneys, which are the chief organs of excretion, are easily stimulated to greater activity if one drinks plenty of water each day. This is one habit that is not likely to be carried to excess.

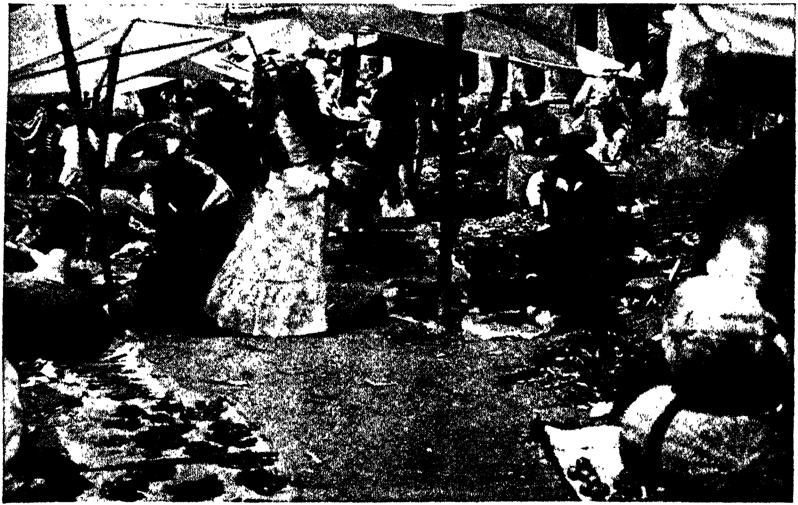
The success of the various water cures offered at fashionable hotels located at mineral springs could be duplicated at home if one would drink as much water as he is inspired to drink at the sanitarium.

FIG. 190.—HUMAN HEALTH

Bacteria in Food.—Since most of the disease germs which are responsible for serious interference with our health, enter our bodies through our mouths or through breaks and wounds in our skin, one of the most important aspects of hygiene lies in the safe-guarding of food against the microscopic agents of disease. Most germs are killed by temperatures near that of boiling water, so the thorough cooking of foods and the scalding of eating utensils are fundamental practices. Foods that are not to be cooked demand extra guarding from contamination. We should know something about the sanitary conditions of the places from which our foods are obtained.

Fruits, vegetables, and other foods that are exposed in markets where people freely handle them, and where flies walk over them with their germ-laden feet, are unsafe things to use unless they are thoroughly washed or cooked.

There is probably no food that is more often the carrier of disease than that best of all foods, our milk supply. While city and state regulations may control regularly bad sources of milk one's final safeguard lies in personal knowledge of the way in which his supply of that food is handled at its source, and in the course of its delivery.



Courtesy Hugo Brehme, Mexico

FIG. 191.—MOST GERMS ENTER THROUGH OUR MOUTHS

The primitive street market, hardly worse than some city markets in our own country. Can you explain what this has to do with the terrifically high death rate in countries that still follow such methods of food distribution?

Decaying food materials may contain disease bacteria as well as the bacteria of decay. Cases of so-called ptomaine poisoning, supposedly due to poisonous products of decay *(ptomaines)*, are rarely if ever due to true ptomaines, but to disease-producing bacteria (for instance, to those producing *botulism*) which take up their abode in decaying or otherwise poorly-kept foods. Avoid all food that shows signs of decay, canned goods that have a peculiar smell, or food that in any other way does not appear, smell, or taste normal. Keeping foods in an ice chest or in a cold cellar will prevent the multiplication of bacteria, but it will not kill the bacteria that are already present.

Bulky foods that are to be kept for some time after they are first cooked, such things as large pieces of meat, soups, stews, heavy puddings, etc., should be cut or stirred or otherwise prepared so they will cool rapidly and not give bacteria a chance to get started at the more favorable, higher temperatures.

The food which remains in our mouths, chiefly on our teeth after we have eaten, becomes the breeding place of disease organisms. The bacteria of decay which develop there may attack our teeth and do damage to them. Consequently the regular use of a tooth brush each day, together with a trip to a dentist at least once a year to make sure that no trouble gets started before we realize it, are essentials of good health. Without sound teeth a mammal cannot properly handle its foods, and decayed teeth may provide the point of entrance for organisms that will spread through the whole body and cause a wide variety of diseased conditions.

Poisons and Drugs

There are poisons and drugs that interfere with health if we put them into our stomachs. It seems strange that the human animal needs to be told to avoid things that are so clearly certain to do harm, and yet the fact remains that the use of such serious habit-forming drugs as morphine, opium, and cocaine is steadily increasing in this country. The rosy dream which attracts the drug fiend is a poor substitute for real living. There is no more helpless victim of disease than the one with whom drugs have worked their havoc. Beware of headache powders and other patent medicines which are the first steps in the formation of drug habits. If you treasure the powers of the life that may be yours, avoid every enticement that would introduce you to these drugs.

There is, again, alcohol, which may damage living protoplasm in a number of ways. Enough men have fallen prey to alcoholism, with its social accompaniments of vice, wretchedness, and poverty, to prove this a habit-forming drug.

There are the less important drugs found in tea and in coffee, but even these taken in quantity may interfere with proper growth and functionings in youth.

There are the poisons in tobacco, and whatever may be said for the mature man's smoking, we must admit that the practice may ruin the health of a youth.

Insidious poisons develop from the wastes that accumulate in our digestive tracts. If these wastes are not eliminated once or twice each day, headaches and a general feeling of depression are going to result. More serious disturbances may follow in another day. A larger proportion of coarse foods (rough cereals, fibrous vegetables, and fruits) in our diets, an increased use of water, especially before breakfast and before retiring at night, and vigorous exercise taken each day are the things that will best correct these troubles.

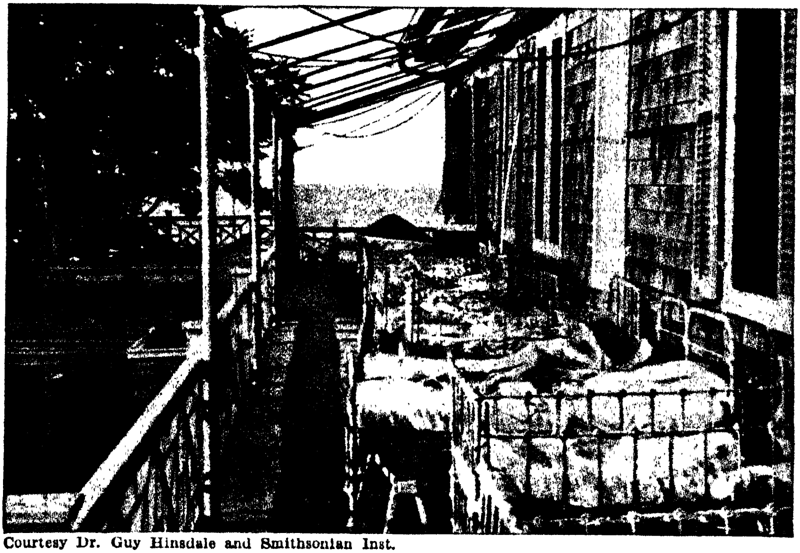
Respiration and Excretion

The wastes that result from metabolism are removed chiefly by respiration and excretion. If these processes are not properly maintained, the wastes immediately become serious poisons.

For the best respiration, we should breathe deeply, utilizing as much of our lungs as possible. This requires an occasionally conscious effort, and it requires such a correct posture as is familiar enough to you.

The air we breathe should contain plenty of oxygen, little carbon dioxide, not too much moisture, and as little dust and as few germs as possible. Nose breathing rather than mouth breathing will keep some of the dust particles and germs from getting into our lungs. Cool air is better than warm air for respiration.

The best air is ordinarily to be found in the out-of-doors, and that is one reason why we should live in the open as much as possible. Our houses should be kept open whenever the weather permits. In the winter, when this becomes a problem, it will still be possible to ventilate indirectly so as to avoid chilling drafts; and at night, when respiration ought to be especially adequate, the bedroom windows should be kept open. Better than that, you might sleep out-of-doors. With warm sleeping garments and bed-clothing, it is possible to remain comfortable in a cold place during all but the most severe winter weather.



Courtesy Dr. Guy Hinsdale and Smithsonian Inst.

FIG. 192.—THE OUT-DOOR SLEEPING PORCH
At a hospital near New York City.

Clothing.—Some respiration takes place directly through the skin. It is therefore important that air reaches the skin. Moreover, the skin of a mammal contains sweat glands, which are important organs of excretion. The more clothing we wear, especially if it is tight-fitting under-clothing, the less chance there is for proper skin respiration and excretion. Loose and porous clothing encourages skin activity, hastening the evaporation of excreted sweat.

In this connection, woolen clothing is to be commended. The individual hairs of wool are wavy, and if not woven too solidly they do not pack together so tightly as the straighter fibers of cotton and some other materials. The air in the open spaces of the wool, being "dead" air, a poor conductor of heat, helps maintain an even body temperature. In winter wool feels warm, its dead air preventing the natural heat of the body from passing out; and in summer its open spaces allow an evaporation of perspiration which is slow enough not to be chilling. In out-of-door activities, woolen shirts and socks are highly desirable equipment, and loosely woven woolen bed-clothing (not solidly woven army blankets) are ideal in our homes as well as out-of-doors.

The use of the minimum of clothing necessary to avoid feeling cold, and air baths taken as frequently as possible, are essentials of skin hygiene. The wearing of over-coats, furs, and other wraps while indoors may be fashionable but unprofitable if one is interested in health.

Water baths taken every day or so are important not only because they remove accumulated dirt and sweat, but because they provide a sort of skin gymnastics that brings a vigorous skin circulation of the blood. Cold baths are better for this purpose than hot baths. A short hot bath followed by a cold one is still better. This is an excellent combination with which to begin a day.

Exercise that stimulates vigorous breathing is the best sort of exercise because, among the other things it accomplishes, it encourages the throwing off of waste products through respiration and through excretion from the sweat glands.

Exercise and Rest

As we exercise we are going to get rid of the old materials in our bodies and encourage the building of new protoplasm with its new stores of energy.

Past generations got their exercise by chopping wood, drawing and hauling water, and doing other hard work about the farm. It was also a good thing for them that they so often had to walk where they went. With the conveniences of modern civilization, however, we let mechanical contrivances and automobiles do all the exercising for us. In consequence we are often too inactive to keep fit. One of the most serious factors contributing to the average poor health of the man over forty, and to many a younger man, too, is his nearly complete avoidance of anything approaching physically hard work or even strenuous play.

FIG. 193.—HEALTHFUL EXERCISE OUT-OF-DOORS

Fortunately, the development of organized athletics and gymnasium work has helped out in recent years. If all of us got into such activities, instead of merely cheering them from the side-lines, we should be better off.

On the other hand, many star athletes overdo and permanently injure themselves.

Courtesy Dr. Guy Hinsdale and Smithsonian Inst.

FIG. 194.—SUNSHINE IS GREAT MEDICINE

These children, suffering from bone and muscle diseases, were cured by exposure to the sunshine of the Swiss Alps.

Exercise within the reach of all of us may be found in such homely things as calisthenics, vigorous walking, running, hill climbing, and swimming. These activities have the great merit of stimulating heart and lung action; and since they are ordinarily pursued out-of-doors, they increase respiration when it may be most effective. Hiking, camping, boating, and canoeing are other out-of-door recreations that bring physical health and mental enjoyment of a superior sort.

Fatigue is nature's signal that exercise and destructive metabolism have gone far enough, and that it is time to rest so the repair processes may catch up. The best rest involves complete relaxation. Every muscle and other organ should be relieved of its work as far as is possible. It is a good thing to lie down while resting, even if it is for only a few minutes in the middle of the day.

Tissues are actively repairing during sleep at night. Learning to get sufficient sleep is a lesson worth acquiring. Too many of us come to regard sleep as a waste of time, to be avoided whenever possible. We hate to give up and go to bed at night. In consequence we are likely to reap poor health sooner or later.

The average boy or girl of high school age needs 9 or 10 hours' sleep every night. Most adults get along on a little less. While many a person manages fairly well on something short of this schedule, the fact remains that the individual who is able to work and play the hardest gets his sleep regularly night after night.

The soundest and most profitable sleep is to be had when one is physically tired but not overtired, when the bedroom is cool but not too cold and the cover sufficient, when the air is fresh, and when the bed is comfortable but not too soft. A short, hot bath taken just before going to bed will encourage sound sleep. If you do not sleep soundly, if you are disturbed by slight noises, and if you dream a good deal, find out what factors favorable to the best sleep are being ignored in your day's program.

Mental Hygiene

The good health of our bodies may be interrupted by injuries and the attacks of bacteria, protozoa, and other organisms. All of the abnormal conditions thereby arising are referred to as diseased conditions. Since an understanding of the nature, cause, and control of disease is so fundamental to human happiness, our next three chapters will be devoted to this aspect of hygiene.

Here, however, we may point out that one's physical health is often (not always) closely related to one's mental health. The man with a perpetually happy view of life, who finds the world interesting and the things in it worth close observation, and the people on a whole kindly and at least curious even when they are most cantankerous, is scheduled for better health than the one who finds life monotonous and people merely provoking.

Just how our minds control physical health is not completely explained. We do know that activities of some of the ductless glands, for instance, accompany such mental states as anger and excitement, and that the secretions of these glands have considerable effects upon the other parts of our bodies. Further, it is apparent that one who is happy and enthusiastic goes about his work with an energy that invites physical exercise and consequently good health. But whatever other explanations there may be. it is certain that it pays to keep happy and interested in the world in which we live.

Keep Busy.—See to it that you work or play each hour of the day. Shun idleness as you would physical injury. When you need to relax mentally, sleep, or start thinking of some new subject. Mental recreation, not loafing, is the remedy for mental fatigue.

Don't stick to one job so long that you get tired of it. A mixture of occupations, some of them called work, some of them so attractive that they may be called play, is good for mental and physical health.

Don't try to make the whole world as you would have it. Take some of it for what it is. Forget things that can't be helped; pitch into the things that remain ahead of you.

Don't let the routine things that have to be done day after day make life monotonous for you. Perform such tasks as washing, dressing, eating, and walking without giving them very much conscious thought. Turn your attention meanwhile to other matters, particularly the brightest and the happiest things that you can think and talk about.

Make good hygiene such an automatic part of your program that it becomes a habit with you. Make the regular cleansing of your teeth, a regular schedule for your meals and for sleeping, the opening of your windows to obtain fresh air at night, good posture, regular exercise, regular bathing, and all the other things, so much a part of your life that you do them without stopping to debate whether or why you should.

FIG. 195.—LOOK AT THE WORLD. BE GLAD YOU ARE ALIVE IN IT!

Look about you. See what an interesting world you are in. Be glad you are alive in it!

SUMMARY

1. Hygiene is that part of animal physiology in which we consider human health. One may enjoy life best and accomplish the most only when in the best of good health.

2. Health involves attention to securing the variety of foods and vitamins which were discussed in the last chapter. Avoid over-feeding, have regular meal hours, drink plenty of water.

3. Foods are prime carriers of disease germs. To be safe they must be thoroughly cooked, or (if fresh foods) they must be obtained from sanitary sources and dealers and protected by being covered or kept cool. Decayed foods may contain disease bacteria. Foods remaining on our teeth may harbor germs that will cause tooth decay and through that cause disease in other parts of the body.

4. The human animal has shown a strange inability or unwillingness to avoid things that are, admittedly, poisons, stimulants, and drugs certain to do more or less damage to health. Poisons from accumulated digestive wastes also work injury to health.

5. Elimination of the poisonous wastes from metabolism is accomplished by respiration and excretion. Vigorous respiration inspired by exercise out-of-doors is well included in the daily routine. Exercise also encourages the elimination of wastes through the sweat glands. Clothing should allow ventilation and frequent bathing should cleanse the skin.

6. Regular exercise is essential for the proper pursuance of destructive metabolism. There is little exercise obtained in sitting on the side-lines and cheering athletes who may be over-exercising at the time. Healthy, out-of-door exercise is obtainable in a variety of ways for all of us.

7. Deliberate rest, with complete relaxation, should follow vigorous exercise. Few of us secure the adequate amount of sleep which would make us most efficient.

8. Physical health is, in some way not completely understood, dependent upon mental health. Keep busy, avoid the monotony of a single occupation or an invariable routine. Perform the essential routine without giving it too much attention, let minor matters go by, give your best attention to the most pleasant affairs of the day. Look at the world, learn of its wonders and richness, of its never-ending store of interesting things. Be glad you are alive in it!

DEFINE

Hygiene

Disease

Sweat gland

PROBLEMS

1. Why is it more healthful to exercise out-of-doors than indoors? List all of the advantages.

2. If one really needed food between meals, would it be better to eat bread and milk, or cakes and candy? Why?

3. Aside from the question of looks, what objections are there to painting and powdering one's face? What would be better remedies for pale complexions and moist skins?

4. What is the objection to a continual use of talcum powder on babies?

5. What six things would you list as the most important that need be done each day in order to preserve one's health?

6. How are people breathing when they snore? Can you produce a similar sound with the mouth closed? With the nostrils closed?

7. What other chapters in this book, other than the present chapter, deal directly with problems of human health?

8. What are the advantages in the present interest in sun baths, skin tans, etc.? What precautions are to be observed?

9. Is there such a thing as plant hygiene? Prove your answer.

10. The section titles in this chapter are Food Hygiene, Poisons and Drugs, Respiration and Excretion, Exercise and Rest, and Mental Hygiene. List, under these several headings, the various things that a gardener might do to further the health of a young tree.

11. List the things that one would need to consider in maintaining the health of some animal pet—for instance, a particular one that you have had.

12. High mountain regions are often particularly healthful. What reasons can you see for that?

13. What changes in the costumes of the girls shown in Figure 193 would add to the healthfulness of their exercise?

14. From the health standpoint, compare the advantages of intramural athletics, and organized, team athletics played against other schools.

15. Name some present-day "health" fads that do not seem based on good physiology.

16. In what ways will you modify your personal hygiene as a result of what you have learned in this unit on physiology?

CHAPTER XX

DISEASE

Much of the sorrow in this world is due to the fact that these marvelously built and delicately controlled living machines of ours do not always function well and profitably. All the parts of an organism, plant or animal, are dependent for correct functioning upon every other part of that body; and whenever one organ functions badly, the entire organism may become upset. It becomes a sick plant or animal, and unless something happens to put the unruly member back into the way of normal functioning, the individual may die.

Abnormal functioning of any part of a plant or animal—any failure to maintain the rate and course of metabolism that is commonly found in an individual of that age and species—is spoken of as *disease.* An upset in a man which causes his heart to beat much more rapidly or slowly than is usual for persons of his age is ordinarily taken as a sign of disease. It is true that there are times, during strenuous exercise or under excitement, when the heart rate will normally increase. There are also many allowances to be made for the fact that no two individuals are alike, either in structure or physiology; and one may have a heart rate that is normal and healthy even when it is higher or lower than the average for other persons. But making all of these allowances, we may say that abnormal functioning of the heart usually represents a diseased condition.

Injuries of organs, such things as cut or burned fingers or broken bones, are not diseases. They are injuries which may and often do interfere with normal metabolism, producing such disease conditions as nervous shock, fever, or blood poisoning; but the injuries themselves are not diseases, as the word is ordinarily defined.

Causes of Disease

An astounding chapter in the story of knowledge, deals with the many and diverse notions that have been held as to the causes of human disease. To primitive peoples and to some moderns diseases are evidences of the workings of evil spirits, demons, banshees, witches, malevolent ghosts of departed enemies, or the evil thoughts of living foes. To meet a ghost and to look it in the eye is enough, according to beliefs in some regions, to put a twist and a lump on the straight man's spine, to make a whole arm withered and paralyzed, to put the pallor and cough of death on the face and in the throat of the strong. How else might one account for the very suddenness of the onset, the lack of visible, material cause, and the tragically fatal ending of disease?

FIG. 196.—DISEASE, POVERTY, AND SORROW

Suspected witches were persecuted and burned as sources of the pestilences that swept Medieval Europe and Colonial America; sick men and mad men were put into dungeons, loaded with chains, flogged, and tortured in order that their evil spirits might forsake them and leave them whole in body and mind.

If there are not evil spirits involved, then there must be outraged gods who are punishing their people for their sins. There are still some who actively oppose scientific attempts to control disease on the ground that it is just punishment which should be endured without an attempt to avoid it.

To all of this, science has one answer: Disease is invariably due to some definite thing which has interfered with the normal functioning of the organism. It may be a failure in some structure within the plant or animal body itself; it may be the attack of a protozoon, a bacterium, or some other foreign organism; but science does not admit the influence of spirits, evil or good, on the development or the control of disease. That scientists are correct is evidenced by the long list of glorious victories being won over diseases which from the dawn of history have been among the worst of the scourges of men.

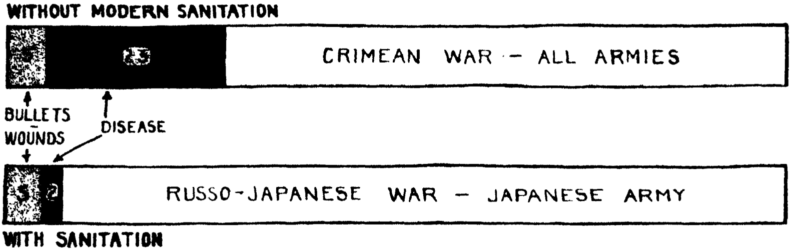


FIG. 197.—BULLETS AND DISEASE

Comparing deaths per hundred men during equal periods in two wars.

Organic Diseases

The known diseases of plants and animals may be classified in two groups, depending on their causes. Those which are due to break-downs in the organs of the organism itself are called *organic diseases.* Those which are due to the invasion of the plant or animal body by other organisms are commonly called *germ diseases.*

When one stops to consider the complex structure of a living machine, and the delicate chemical adjustments (through vitamins, enzymes, and hormones) necessary to keep it in perfect order, it is not surprising to find that it occasionally gets out of order. It is, indeed, more surprising that it ever does manage to make all the complicated connections on which the good health of the organism depends.

Abnormalities in Ductless Glands.—We have already described (Chapter XVIII) some of the abnormalities resulting from the ill-function of ductless glands. We have noted several types of thyroid disturbances. We have mentioned diabetes, upsets of the rate of growth, and excess stimulation from the adrenal glands as conditions following disturbances of ductless glands.

Nutritional Diseases.—We have also mentioned such failures in assimilation as scurvy and rickets, due to the lack of certain vitamins in the diet. Unbalanced diets, diets which fail to have reasonable proportions of the four classes of foods, may also produce diseased conditions. There is evidence that the mysterious disease called pellagra, common in Europe and recently important in this country, is not a germ disease but a nutritional upset due to a lack of fresh proteins (or possibly a vitamin) in the diet.

Nervous Disorders.—Other organic diseases are nervous disorders, due to over-stimulation of the nervous system with poisons or drugs; to the fatigue which continuous excitement or dull routine may cause; to great and sudden excitement producing what we call nervous shock; to the heredity of deficiencies in the nervous structure; and to still other conditions. Some of the mental disorders which produce some forms of feeble-mindedness and of insanity are organic diseases, although some other mental diseases are due to attacks of germs on the tissues of the central nervous system.

Anemia.—Organic diseases include such a thing as pernicious anemia. In this disease there is a reduction in the normal and necessary number of red corpuscles in the blood. It was a triumph of biological and medical science, when it was recently discovered that this condition may be corrected by the inclusion of considerable liver or of prepared liver extracts in the diet of the afflicted individual.

Heart Diseases.—These are increasingly important. They may be due to bad habits of diet, to over-stimulation of the heart nerves, or to other factors not well understood.

Cancer, standing out as one of the most serious of modern diseases, is apparently organic in nature. In this disease the cells of some part of the body grow at too fast a rate, producing over-abundant tissue which may so interfere with the normal functioning of that part of the body as to prove fatal. Medical science has learned how to control the abnormal growths if they are treated in the earliest stages of their development, and we look forward to the day when complete knowledge of their cause will give us complete control over them.

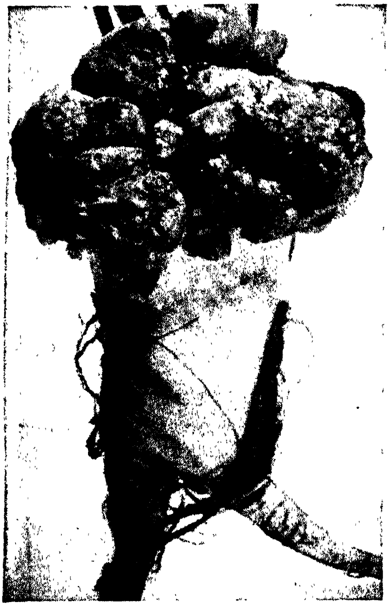

Courtesy E. F. Smith

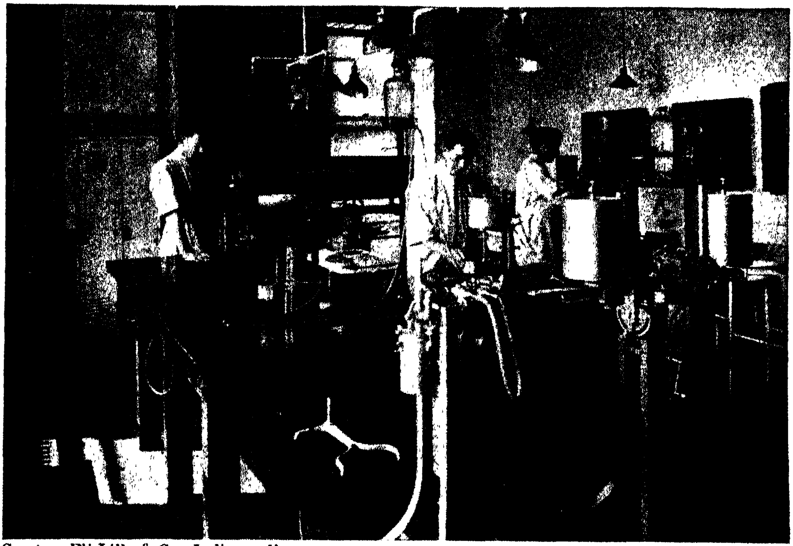
FIG. 198.—PLANT CANCER
Super-abundant tissue formation on sugar beet root.

Control of Organic Diseases

The above is a very incomplete list of organic diseases of the human, and it makes no mention of the organic disturbances which occur in plants and other animals, and which are as truly diseases as diabetes, heart disease, or cancer in man. Enough, however, has been given to show the wide variety of the abnormalities which appear. Just a word need be said about their control.

The most important step in the control of any kind of disease is its prevention. Cures for conditions that already exist can only prove second lines of defense against the invader.

There are, however, limitations to the prevention and cure of disease by the practice of good hygiene. It is true that vigorous exercise, the pummelling of muscles, a daily dozen, the considerable drinking of water, and the mere thinking of happy thoughts will prevent and even cure certain types of irregularities.



Courtesy Eli Lilly & Co., Indianapolis

FIG. 199.—THE CONTROL OF DISEASE DEPENDS ON CAREFUL SCIENTIFIC RESEARCH

In the modern laboratory, where our knowledge of drugs, gland products, serums, etc., is based on the most recent developments of chemistry and biology.

The Physician's Advice.—There are, however, certain organizations and cults which preach that *all* diseases may be controlled by such hygiene. Nothing could be more at variance with our scientific knowledge of disease. In the treatment of both organic and germ diseases, we must utilize all of the results of the most recent research in physiology, and in the other fields of biology and chemistry. A young physician, well-trained in a reputable medical school, or an older man who, you are certain, has kept in touch with the recent advances of medical science, has the knowledge which will provide whatever cure is known. The would-be doctors practising special fads and doctrines do not have anything like an adequate command of modern science.

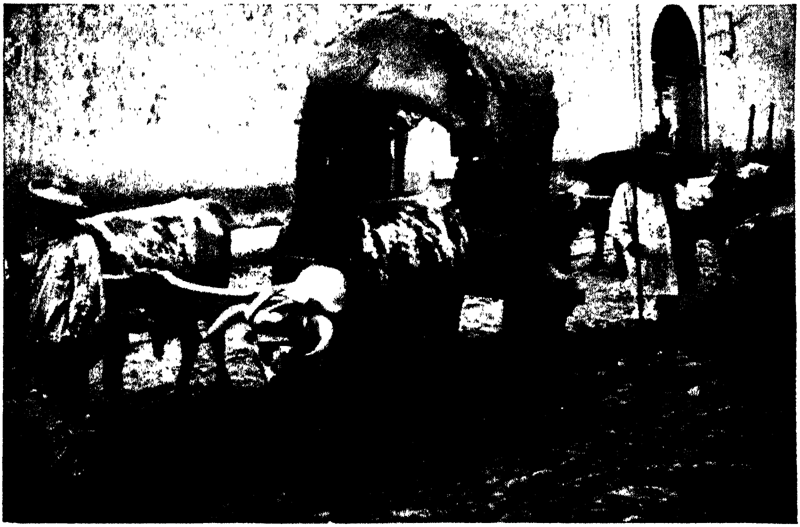
Neither the information in this chapter on disease, nor the information which you, as an average citizen, may acquire, can be sufficient to allow you to cure your own ills and ailments. The cure-all in the patent medicine bottle is a proved fake. Even the reputable drugs handled by your druggist are useless things or dangerous poisons if administered without the prescription of a physician.

If good hygiene has failed to prevent the upset of your normal metabolism, your part in the control of the disease is to betake yourself, early in the course of the upset, to a reputable, well-trained physician. He it is who may utilize the results of scientific research and provide the means of control of ills from which man has never before had real refuge.

Germ Diseases

Hippocrates, a famous Greek physician who lived four hundred years before Christ, taught that diseases were due to disturbances within the body of the victim. He also had some vague understanding of the fact that something other than demons and evil spirits might be present in the air, food, or water with which we come in contact; and that these substances, passing into our bodies, might be responsible for some of the upsets that follow. Thus was born the germ-theory of disease.

Hippocrates recommended the boiling of drinking water as a means of controlling the agents of disease; and we now understand that his teaching was good. During the Middle Ages, however, "the officials boiled witches instead of water," and sanitation gave way to filth and pestilence. It was not until the invention of the microscope made it possible to see bacteria that the way was paved for the study of the microorganisms (microscopic organisms). These, the so-called *germs,* are bacteria, protozoa, roundworms, or still other forms which, we now know, actually invade plant and animal bodies and thus become responsible for some of their ills.

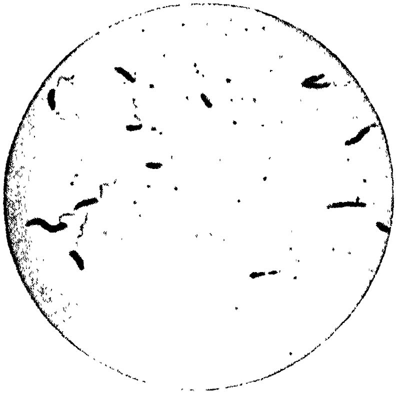


Courtesy Hugo Brehme, Mexico

FIG. 200.—PRIMITIVE SANITATION, DISTRIBUTOR OF DISEASE

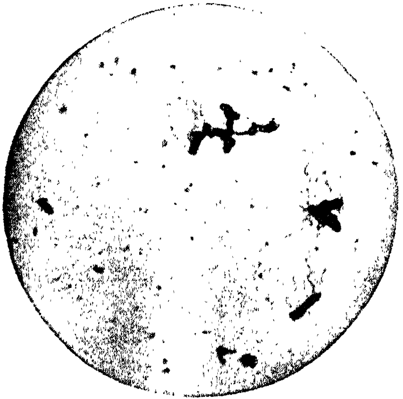
Note the open sewer flowing down the center of the street. Ignorant of the nature of disease, large portions of the world still tolerate primitive methods that result in the widespread distribution of typhoid and other intestinal upsets, with consequent death rates that are appalling.

Proved Relations of Germs and Disease.—We have already pointed out that it was Louis Pasteur, the great French biologist and chemist, who finally proved that even the microscopic organisms do not come into existence through spontaneous generation. Pasteur's experience with this subject qualified him to undertake a study of the causes and the means of control of a silkworm disease (pébrine) which was ruining the silk industry of France. For five long years he labored on the problem, working with insufficient equipment and facing ridicule and bitter opposition from the learned and silk-growers alike. In the end, however, he proved that the black spots in the bodies of the caterpillars marked the presence of microscopic protozoa, and that these were responsible for the diseased conditions of the caterpillars. He proposed that the growers destroy all the germ-laden eggs of the silkworm, and grow their caterpillars only from eggs proven by the microscope to be free of germs and, therefore, free of disease. Because of the bitter skepticism of the growers, Pasteur had to take over the actual management of a badly infected establishment and prove that it was a simple matter to control the disease by controlling the organisms that produced it. Thus was an important industry saved for France; and thus, not many years ago,



Courtesy Dr. Max Poser,
Bausch & Lomb Optical Co.

FIG. 201.—CHOLERA BACTERIA
As they would appear through the microscope. Magnified 1,000 times.

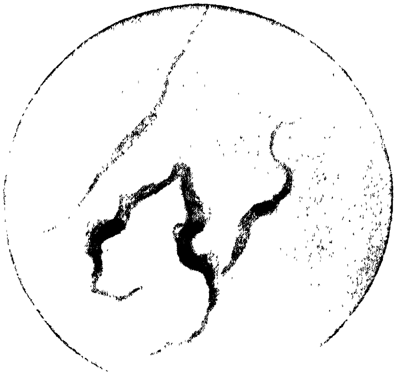


Courtesy Dr. Max Poser,
Bausch & Lomb Optical Co.

FIG. 202.—TYPHOID BACTERIA
Germs of one of the most serious of human diseases. Magnified 1,000 times.

even within the memory of living men, Louis Pasteur gave the first clear-cut proof that micro-organisms are responsible for some of the diseases of higher organisms.

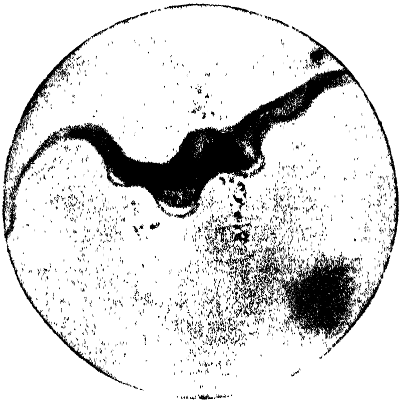
Bacterial Diseases.—The further researches of Pasteur, and the work of a long list of heroes of science who have dared to handle and study the germs of pestilence and disease have, within this little more than a half century, shown us that scores of human afflictions are germ-produced diseases. The list of bacteria now proved to cause disease includes those that produce boils, abscesses and the pus in wounds and bone infections, the highly fatal lung disease called broncho-pneumonia, scarlet fever, septic sore throat, pneumonia, meningitis (also called spotted fever), gonorrhea (a disease of the uro-genital system), anthrax (a cattle disease sometimes occurring in man), diphtheria, typhoid fever, paratyphoid fever, some of the intestinal infections producing diarrhea and dysentery, the newly prominent undulant fever (Malta fever), some of the widespread disturbances of



Courtesy Dr. Max Poser.
Bausch & Lomb Optical Co.

FIG. 203.—A DISEASE-PRODUCING PROTOZOON

A rat-inhabiting species related to the organism that produces sleeping sickness in man. Magnified 1,000 times.



Courtesy Dr. Max Poser.
Bausch & Lomb Optical Co.

FIG. 204.—THE ABOVE PROTOZOON MAGNIFIED 3,000 TIMES

A remarkable photograph, representing the upper limits of the modern microscope.

the body which accompany tooth infections, bubonic plague, tularemia (a ground-squirrel and rabbit disease that may attack man), lockjaw (tetanus), gangrene, whooping cough, botulism (a deadly form of food poisoning sometimes but incorrectly considered ptomaine poisoning), tuberculosis, leprosy, glanders (a disease of horses and related animals), cholera, and still other causes of calamity. We have already named the plant disease called fire-blight, crown-gall, citrus canker, black rot of cabbage and turnips, bean blight, and the common scab of potato which are the results of bacterial activities. What a long list of torments, what ages of human sorrow and suffering, what armies of the dead this list of names brings to mind! What a flood of hope one finds in our present knowledge of the true causes of these diseases, and the already partly-filled promise of their control.

Protozoan Diseases.—Human diseases more or less clearly proved to be caused by protozoa include some of the worst forms of dysentery, forms of sleeping sickness that occur in Africa and South America, malaria, Texas fever of cattle, the pébrine disease of silkworms, and still other diseases of other animals and of plants.

Worm Diseases.—Next to the bacteria and protozoa, certain of the roundworms and flatworms are the most important organisms producing diseases in man. Many of these worms are of fair size, and the popular term germ hardly applies to them. The diseased conditions for which they are responsible are therefore often spoken of as parasite-produced diseases, but since the most important of the worms are microscopic, here we may include them as germs of disease.

Larger species of worms are so very common in the bodies of many animals that they may rank with the protozoa in importance; but in man they are less common. Tapeworms, intestinal roundworms, and pinworms have already been named as trouble makers among the larger species.

Among the more microscopic worms, there is the **trichina worm** which commonly occurs in hogs, rats, mice, rabbits, and other mammals. Pork that is not well cooked provides the usual means of entrance into the human. In the course of epidemics as many as 2,000,000 trichina larvæ have been found in a pound of pork. The resulting disease in man, trichinosis, may become very serious, proving fatal in a third of all cases. Some control of some kinds of worm infestations is secured through government inspection of pork; but since it has proved impracticable and impossible to discover all pork parasites, there is at present no government inspection for trichina. Control of the trichina worm therefore depends on one's personal precaution in eating only meat which has been well cooked.

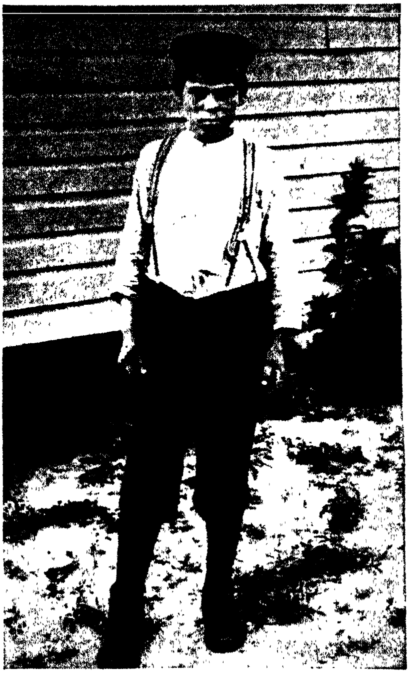

Courtesy U. S. Public Health Service

FIG. 205.—17 YEARS OLD!
A victim of hookworms.

The most serious disease produced by a roundworm is the **hookworm disease** which is found in many warmer parts of Asia, Africa, and the Americas, including the southeastern portion of the United States. The victims of this worm are typically pale, puny, lazy, dull, indifferent, careless, shiftless. With the infestation continuing year after year, whole communities become characterized by a type of ignorance, poverty, and backwardness that, fifteen years ago, was appallingly common in the infested area. The white race seems more susceptible than others. The efficiency of laborers afflicted with hookworm may be reduced to hardly 50 per cent of their normal, and the economic damage is consequently great. Death often occurs. Hookworm and malaria have been greater obstacles to the progress of parts of our South than all other items of history, economic condition, and geographical location combined.

Adult hookworms normally live in the intestine of their host. Their eggs pass out with digestive wastes and the ground in regions of primitive sanitation becomes severely infested with the young larvæ. These larvæ attack new hosts by burrowing through the skin, and the habit of going barefooted, especially common among children in the South, provides the means by which most infections are acquired.

There are three weapons by which the hookworm disease may be controlled. The victim may be simply and effectively treated with medicines that the physician has found available; the regular wearing of shoes will largely prevent new infections; and the introduction of sanitary systems which will prevent soil pollution may completely eliminate the disease from any region. Due to the activities of the Rockefeller Foundation, the disease is disappearing from this country, and one of the fairest parts of our land will thus be given an opportunity to show its true worth.

Other Germ Diseases.—In addition to the diseases named above, there are many which bear all the ear-marks of being produced by living organisms, although no organisms can be discovered in the affected tissues. These diseases multiply and spread and are contagious in the same way as those caused by bacteria and protozoa, and they can be controlled by the very same methods. There must be living organisms too small to be evident under our microscopes, and yet capable of causing diseases. Whether these are plants, animals, or something else, nobody can say. Since they are small enough to go through the microscopic spaces in porcelain or earthern filters, they are called *filterable viruses*. The so-called mosaic diseases of plants appear to be caused by such viruses. In animals, smallpox, rabies (the disease so often transmitted to man by the bite of a dog), measles, foot-and-mouth disease (of cattle and sometimes of man), and infantile paralysis are virus diseases. Rocky Mountain spotted fever, typhus (poorhouse fever, jail fever), and trench fever are caused by very minute organisms which, although they have been detected under the microscope, are no better understood than the filterable viruses.

Such common diseases as mumps, colds, and influenza are still among those whose causes are not known, although we suspect that micro-organisms are responsible.

How Germs Produce Disease

The bacteria, protozoa, or other organisms which attack the higher animal or plant produce disease in two ways. In the first place they may cause actual destruction of the tissues or cells of the host. This is the way in which bacteria work to produce boils and abscesses, blood poisoning, the damage to the digestive tract in typhoid, cholera, and dysentery, and the damage to the lungs in pneumonia and tuberculosis.

By a second method, micro-organisms produce, in the course of their own metabolism, poisonous substances known as *toxins*, or other poisonous substances which, distributed throughout the body of the host, work great damage to it. This is the way in which most of the germs of disease work.

Thus may we summarize our knowledge as to the causes of disease. In the following chapters we shall follow the story of the conquest of germ diseases through the discoveries of modern science.

SUMMARY

1. An abnormal functioning of any part of a plant or animal is a disease.
2. While diseases were formerly ascribed to evil spirits or evil thoughts, science has shown that disease is the result of some interference with the normal metabolism of the plant or animal.

3. Some diseases are due to break-downs in the organs of the organism. These are called organic diseases. Ductless gland disturbances (goiter, diabetes, growth disturbances, etc.), nutritional diseases (scurvy, rickets), nervous disorders, anemia, heart diseases, and cancer are in the list of organic diseases.

4. Sometimes organic diseases may be prevented by the exercise of good hygiene. For the cure of most organic diseases we must rely on the knowledge of the well-trained physician to whom we should go early in the course of the upset.

5. Germ diseases are caused by the attacks of micro-organisms, as was first proved less than seventy-five years ago by Louis Pasteur, the French biologist.

6. Diseases caused by bacteria include scarlet fever, pneumonia, diphtheria, typhoid and paratyphoid fevers, bubonic plague, tuberculosis, many plant diseases, and others.

7. Protozoan diseases include severe forms of dysentery, sleeping sickness, malaria, Texas cattle fever, and others.

8. Diseases produced by roundworm attacks include trichinosis. This is to be controlled only through the thorough cooking of pork meat. Hookworm disease, one of the most serious of worm diseases in warmer parts of the world, may be avoided by preventing ground pollution and by the wearing of shoes. It may be cured by drugs that the physician can administer.

9. Such diseases as smallpox, measles, infantile paralysis are produced by filterable viruses. These seem to be organisms that are too small to be seen under the microscope.

10. Germs produce disease either by destroying the tissues of their hosts (as in boils, typhoid, pneumonia, and tuberculosis), or by producing toxins which poison the host (as in most germ diseases).

The control of germ diseases will be considered in the following chapters.

DEFINE

Disease
Organic disease
Anemia
Cancer
Physician
Germ disease
Micro-organism
Hippocrates
Louis Pasteur
Trichinosis
Hookworm Disease
Filterable virus
Toxin

PROBLEMS

1. The word *germ* is used with several totally different meanings in biology. Define as many of these as you may know.

2. Make a list of the diseases that have ever attacked you, your relatives, or immediate friends. Classify the diseases as organic, bacterial, protozoan, worm, or other germ diseases.

3. Make a list of the diseases which you have actually observed in animals other than man.

4. Make a list of all of the plant diseases which you have actually observed.

5. Is it healthier to forget about disease and to think continually of good health? Or to learn something about the causes and nature of disease? Explain why.

6. Was primitive man more or less afflicted than civilized man with disease? Be prepared to debate this with others in the class.

7. Where is disease most abundant: in the city, in the country, or in suburban communities? Try to find definite information on this subject. Try to explain why disease is more common in one place than in another.

8. What important diseases occur in other parts of the United States, although they do not occur in the region in which you live?

9. Which of the diseases which occur in your part of the country are common there because of peculiar living conditions (geographic, food, industrial, etc.) which are found in the region?

10. List some diseases that more commonly occur in children; some that are more common in older people. In each case, try to explain why the disease is concerned with particular ages.

11. List some human diseases which, as far as you know, are as yet incurable.

12. List some diseases that were once incurable, but which are now curable because of recent increase in our scientific knowledge.

13. Why are some people healthier than others? (Many factors are involved in such differences.)

14. Why is a wound on a plant more liable to fungus attack than a healthy part of the same plant?

15. Bacteria and protozoa are the commonest disease germs in animals. Fungi more often do the damage to plants. Explain why there is this difference.

CHAPTER XXI

CARRIERS OF DISEASE

For thousands of years the winds, the damp airs and gases of the marshes, and the dust-laden air of the city have been connected in the minds of men with the spread of pestilence and death. Both primitive and more civilized peoples have held a great dread of the chill dews and breezes of the night, believing that the night air carried disease, spirits, and witches. Even at the time of our Civil War, in a large volume published by our own American government, malaria was still described as due to *miasmas*—mysterious, disease-bearing vapors—which arose from neighboring lowlands.

Air Transportation of Germs

The first studies on bacteria indicated that they occur in abundance in the air. It is now estimated that a man in a large city may breathe 300,000 or more bacteria each day. This seemed to provide a very natural explanation of the way in which disease germs were spread. Pasteur showed that materials in which all bacteria had been killed would not decay unless they were exposed to the air when, thereupon, they began to decay. Thus he proved that *bacteria of decay* ride to work on dust particles in the air. Knowing this, Sir Joseph Lister, the great English surgeon who developed our modern methods of disinfecting and excluding germs from wounds, at first tried to prevent disease by spraying germicides (poisonous materials that are germ killers) in the air of rooms where disease had occurred.

Since then we have learned, however, that even though bacteria of decay and some others are common in the air we breathe, the germs of disease are rarely found afloat in that same air. Most disease germs are quickly killed by direct sunlight, and they live primarily in moist conditions. The disease germ that chooses to ride to battle on a speck of dust will probably fall victim to the brilliance and aridity of the journey. It has been demonstrated that even the disease-laden breath of a consumptive is not dangerously charged with germs by the time it has gone an arm's length from him. When droplets are coughed out of the mouth or sneezed out by the patient, the germs may be spread somewhat farther unless a handkerchief has been properly employed. But patients ill with contagious germ diseases may be placed in hospitals in wards with others without danger of air-borne infection. Doctors and nurses may safely attend cases of contagious diseases if they are careful to avoid direct contact with the patients, or if they take steps to destroy any germs they may pick up when it is necessary to make such direct contacts. While the air is the great transportation system for bacteria of decay, fresh air conveys few disease organisms.

Direct Contagion

Germs of human disease, then, are ordinarily transported from one victim to the next in liquid or solid materials. Often the transfer depends on direct contacts which the diseased individual may make with some well man.

Infection and Contagion.—All germ diseases are spoken of as *infectious* diseases, meaning that they are due to the *infection*, to the invasion of the body of the host, by living organisms.

Diseases are spoken of as *contagious* if they are produced by germs which can pass from one human host directly to another whenever the two come into actual contact. They are called *contagious* from the Latin spelling of the word *contact*.

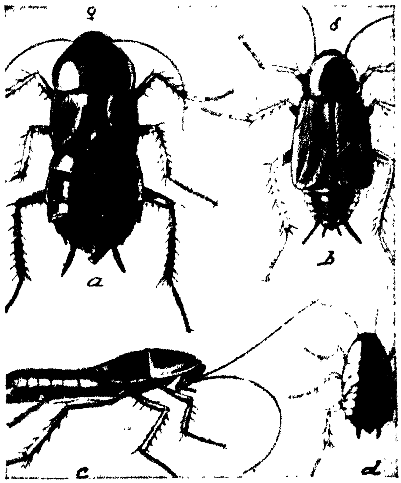
Not all germ diseases are contagious. Such diseases as yellow fever, malaria, bubonic plague, and typhus fever are not contagious, although they are infectious. They depend on some other means of transportation from one human victim to the next. The list of truly contagious diseases includes measles, mumps, scarlet fever, whooping cough, chicken-pox, smallpox, tuberculosis, typhoid and paratyphoid fevers, several forms of dysentery, septic sore throat, and others.

Paths of Contagion.—The portals through which most disease organisms enter their hosts are three: wounds, the openings of the respiratory system, and the mouth. The solid, unbroken skin of a higher animal, like the bark of a tree, is practically a germ-proof covering. This fact explains why our bodies are not consumed by bacteria as soon as we are born. Breaks in the skin, trivial as they may be as direct injuries, become important sources of germ infection and need protection with germ-free dressings of fine cotton gauze or absorbent cotton. If wounds are washed, the water should have been boiled to rid it of disease germs; and in any case wounds should be treated with some germicide, such as 70 per cent alcohol, mercurochrome, or argyrol. Peroxide and iodin are not so safe to use, for in excess they may damage living tissues. Warm soap suds are germ-destroyers of some value.

The respiratory openings do not often provide entrance for disease organisms when the respiratory system is healthy and whole. Most of the germs that are conveyed to the nose are caught in the outer ducts or quickly destroyed when they get farther in. Of course, germs of colds enter our noses and throats with distressing frequency. But such respiratory diseases as pneumonia and tuberculosis do not often attack sound lungs, although they attack very quickly if some sort of injury occurs to the respiratory system.

Most of the germs that reach us, according to some estimates about 90 per cent of all disease organisms, enter through our mouths. The food that we eat, the water that we drink, the ten fingers that we own, towels, handkerchiefs, public drinking cups, and all other things that come into direct contact with our mouths are agents for conveying germs from a previous case of illness to our own bodies. Many of these disease germs find the best conditions for their development in the digestive tract itself; in other cases they spread from there to some other part of our body.

It is because the mouth is such an important avenue of infection that the safe-guarding of our water supplies, of our milk supplies in particular, and of all uncooked food becomes of prime importance in civic and personal hygiene. We have already given some attention to this subject of food hygiene.



Courtesy U. S. Bur. Entomology

FIG. 206.—THE ROACH: A MECHANICAL CARRIER OF DISEASE

One of the commoner species; *a*, the female; *b*, the male; *c* and *d*, the young. About natural size.

Insects as Mechanical Carriers

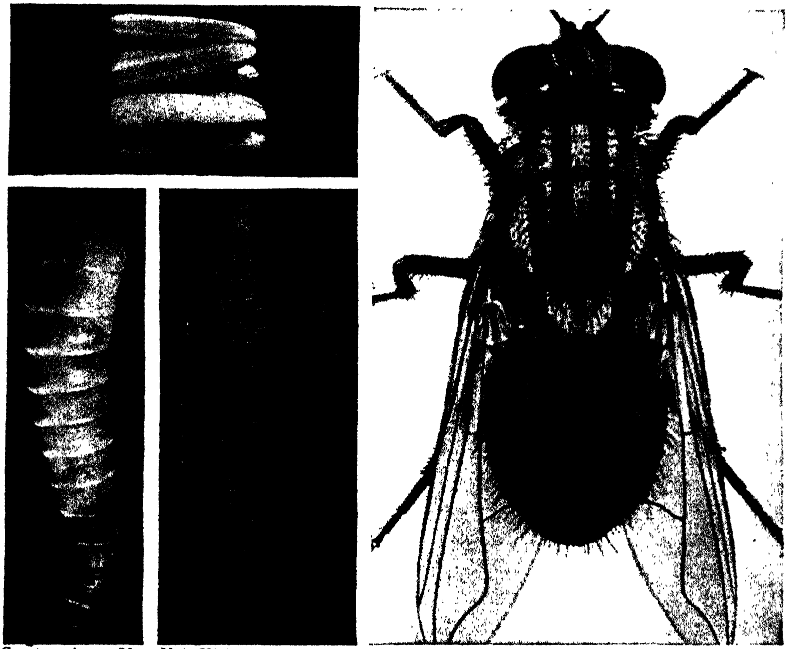
Experience has shown that even when we avoid actual contact with contagious diseases, their germs still reach us. There are, moreover, the diseases which are infectious but not contagious. How are such diseases distributed? Where are the airplanes by which their germs travel?

Insects are the six-legged, two- or four-winged planes on which some of the germs swarm to battle. An insect, coming into direct contact with a case of disease, or with food, clothing, excretions, or other materials from a diseased individual, may pick up disease germs on its own body and carry them to the food, water, milk supply, or open wounds of the next human victim. In this way some of the insects become prime factors in human health. If the household insects, the body lice, and the flies and other species that congregate about our foods are disgusting enough as pests, they are more important as the agents of disease and death.

Any insect that lives regularly with man, in his home or close to his dwelling place, may act as a mechanical carrier of disease. House flies, stable flies, blow flies, horse flies, various biting flies, biting gnats and midges, mosquitoes, cockroaches, bedbugs, pantry beetles, body lice, and fleas are the insects most often involved. Various chiggers, mites, and ticks, all of which are arachnids related to but not true insects, are also mechanical carriers of disease. Many of these same organisms similarly carry germs of disease to other vertebrates, causing great losses among horses, cattle, sheep, swine, chickens, and other domesticated animals. Insects also carry the spores of many of the fungus diseases that work damage to cultivated plants.

Roach.—Among these mechanical carriers of disease, there is that repulsive creature, the roach. A large number of the houses in this country are infested by the insect. Some of our American cities—in fact, most of our American cities—do not have a single restaurant or hotel that is not over-run by roaches. Conditions become worse farther south because the roach belongs to a primarily tropic tribe. There are parts of the Southern United States where the passenger trains carry a population of roaches. These insects are rarely evident in the daylight, and most people do not know that the food served in three out of four public eating places comes from roach-inhabited kitchens where it may have been soiled by insect excrement and mouth regurgitations. Perhaps most of us would prefer not to know such things. Our ignorance, however, will never prevent any insect from spreading illness and death.

As far as we know, the roach is not the principal distributor of any particular disease of the human, but it is proved capable of carrying tapeworms, tuberculosis, typhoid, anthrax, Asiatic cholera, and other germs, in all a total of fifty-two kinds of organisms that may afflict man and the domestic animals. Ordinarily roaches may be got rid of by thorough house-cleaning. If the corners and out-of-the-way places in and about our houses are kept free of accumulations of dirt we may hope to avoid these insects. In solid city blocks and public kitchens community coöperation will be necessary. But in any event, it is a severe indictment if we continue to endure the presence of roaches.

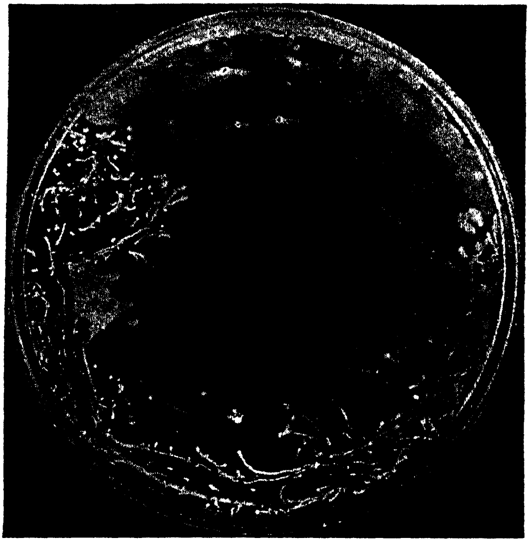


Courtesy Amer. Mus. Nat. Hist.

FIG. 207.—THE HOUSE FLY, DISEASE CARRIER

Eggs, larva, pupa, and adult.

House Fly.—The house fly is probably the most important of the mechanical carriers of insect-borne diseases. This is due to the fact that the insect lays its eggs in human excrement, horse manure, and other decaying matter. It lives there as a larva, and as an adult passes back and forth from those places to the foods on our tables. The fly's sticky feet are well equipped for carrying disease organisms. They are known to spread tuberculosis, dysentery, infantile diarrhea, Asiatic cholera, ophthalmia (a serious eye disease), and typhoid, as well as several of the parasitic worms that infest the human. A complete list of the germs carried by this single insect would be startling in its length. Although the list we have given for the roach is similarly long, the house fly, because of its abundance everywhere, and its constant contact with our foods, becomes the most serious problem of medical entomology throughout most of the United States.



From Herms' Medical Entomology. Courtesy Macmillan Co.

FIG. 208.—COLONIES OF BACTERIA
Where a house fly has walked.

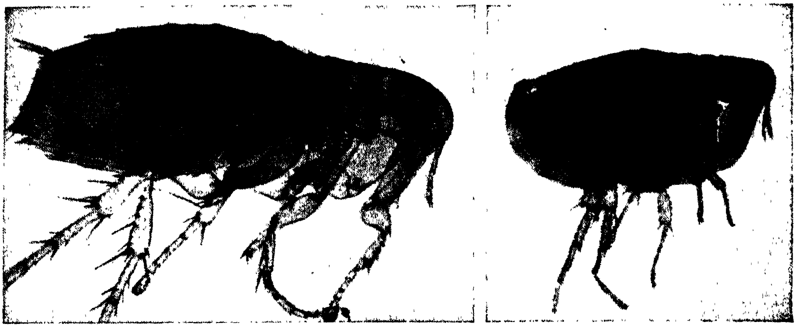
Typhoid bacteria are commonly spread by drinking water supplies that are contaminated with sewage. They are also distributed through milk supplies and by direct contact. The house fly is, however, another important agent of distribution of the disease. During epidemics, one and a third million bacteria may be the average number carried by each fly.

Flies most often live in horse manure, but they are most dangerous when they inhabit human excrement, a breeding ground for the germs of several serious intestinal diseases. Cities with sanitary sewage systems and laws requiring that manure heaps in stables be tightly enclosed are fairly safe against fly-borne epidemics. Human health may be just as safe in the smaller towns and on the farm, but in many rural communities conditions are very bad. Open privies should be destroyed, or so maintained and supplied twice each week with chloride of lime that the house fly cannot possibly breed in them. Jacksonville, Florida, with a typhoid death rate of 106 per thousand in 1910, finally required that its open privies be closed; and its death rate from that disease dropped to twenty-six in 1912. Clearly the fly is another insect which we cannot afford to have visiting foods in meat shops and pantries, and on our tables!

Courtesy Maine Agric. Exp. Sta.

FIG. 209.—PLANT LICE THAT DISTRIBUTE THE POTATO MOSAIC

Plant Diseases.—One other recently discovered relation of insects is their service as mechanical carriers of plant diseases. The loss of food crops from the plant diseases called rusts, wilts, mosaics, rots, and cankers is enormous, and insects may be partly credited for that. For instance, the valuable seed-potato crop of the Aroostook Valley in the state of Maine has a serious enemy in a mosaic, a disease that spots the leaves and consequently kills the plants. Recently it was found that plant lice were carrying the organisms of this disease from wild roses on which the lice live early in the year to potato plants which are their hosts later in the season. It seems a strange way to protect the potato crop from disease by destroying the wild rose bushes of the region—but such is the remedy.



Courtesy C. T. Brues and Harvard Univ. Press

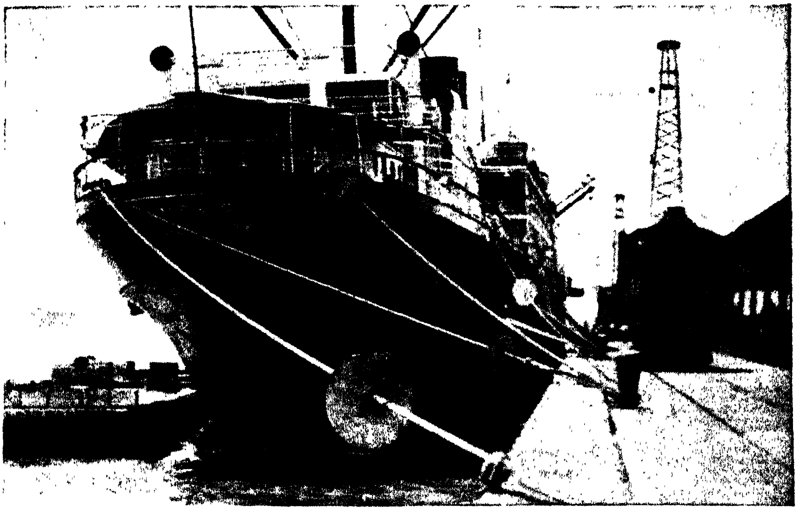
FIG. 210.—RAT FLEAS, CARRIERS OF BUBONIC PLAGUE

Northern and tropical species.

Necessary Mechanical Carriers of Disease

Sometimes insects are more than the occasional carriers of disease organisms. They are the *necessary* mechanical carriers of disease. The disease organisms cannot be distributed by any other agency but these particular insect hosts.

Fleas.—This is the status of bubonic plague, which is one of the most fatal diseases that this world has ever known. During the fourteenth century 25,000,000 people, one-fourth of the total population of the whole of Europe, perished from this "Black Death." During the first ten years of the very century in which we are living the death rate from this disease in India was nearly 1,000,000 persons per year. We are actually in the declining years of a great bubonic plague epidemic, although Western Europe and America have largely avoided the catastrophe because we now know how the disease is distributed.

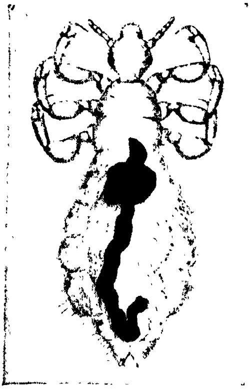


Courtesy U. S. Public Health Service

FIG. 211.—KEEPING BUBONIC PLAGUE OUT OF OUR COUNTRY

Rat-guards on the hawsers prevent flea-infested rats from coming ashore.

The bubonic form of plague cannot be passed from man to man by direct contact. The bacteria have to be drawn from the blood of an infected animal and injected into the blood of the next victim by certain common insects, namely fleas! Rat fleas, and in California the fleas of ground-squirrels, are the usual carriers. The modern methods of control consist in killing rats and ground-squirrels, and in preventing rats from reaching our shores by way of foreign steamships. When bubonic plague broke out in San Francisco in 1900, and in New Orleans in 1914, the U. S. Federal Health Service took drastic steps to exterminate rats in those cities, even tearing down whole blocks of rat-inhabited shanties. The dread disease is everlastingly waiting to get into this country. Our safety depends upon our success in engaging with infested animals and the fleas that live upon them.



Courtesy C. T. Brues and Harvard Univ. Press

FIG. 212.—BODY LOUSE, DISEASE CARRIER

Body Lice.— One of the most important of recent discoveries is the rôle of human lice, chiefly the body louse, in disease transmission. Cooties were talked about during the World War, but since then they have dropped out of the conversation of polite society. Nevertheless, the sooner we recognize that a large proportion of the world is still infested by lice, the sooner we may prove our dominance over those insects. The peasant populations of Mexico, South America, Egypt, Servia, Eastern Europe in general, Russia, India, and China, are to a great extent infested with lice. Practically all of our American jails breed the pests. In the jails of Bolshevik Russia, vagabonds and college professors joined in a vain effort to remove the lice from their clothing.

Until 1909 lice were classed merely as pests, but in that year it was discovered that the body louse is a means of transmission of typhus fever. Much more recently it has been found that fleas are also carriers of the typhus organisms in our own country. Typhus has raged wherever there have been poverty, war, or other bad living conditions. It is estimated that over 1,300,000 cases occurred in England and Ireland in 1847 and 1848. Typhus killed more victims during the Thirty Years War than all of the weapons of warfare. In every war of history there have been great epidemics. Typhus was in part responsible for the military failure of the Balkan States in the World War. In little Serbia, then only half again as large as the state of Maryland, the typhus deaths in April, 1915, numbered 9,000 per day. By reckoning how quickly your own town would be destroyed by that death rate, you may gain some notion of the importance of this insect-borne disease.

Also recently, 1918 to be exact, it was discovered that trench fever is carried by the body louse. The victim, scratching his louse bites, works the infected louse excrement into the wound and thus contracts the disease. It is said that during the World War a million men of the allied armies were sent to the hospitals with trench fever, and although the cases were not often fatal, the loss of man power was tremendous. These and other louse-borne diseases do not occur in the United States so commonly as in many other countries, but we are liable to them as long as any of our population harbors lice.

Courtesy Smithsonian Inst

FIG. 213.—DR. LAZEAR

Who gave his life in proving the mosquito transmission of yellow fever.

Intermediate Hosts of Disease

Other insects bear a still more intimate relation to human ailments. These are the *intermediate hosts* of certain disease organisms. The organisms cannot complete their life cycles unless they can live for a time in certain insects and for another time in the human body. If either the insect or human host fails it, the disease organism dies.

Mosquitoes and Yellow Fever.—Yellow fever is one of the best-known diseases in which insects are intermediate hosts. Its germ depends on the mosquito for its transportation.

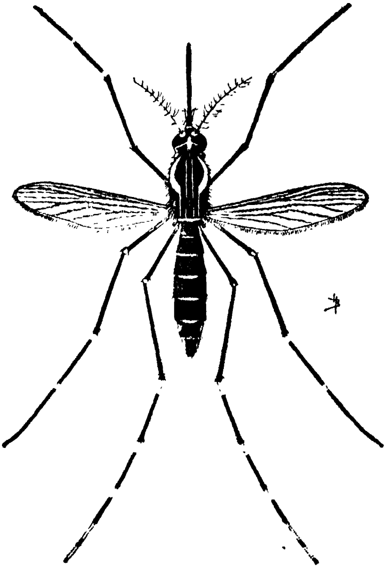
Yellow fever occurred in the United States chiefly in the South. It was, furthermore, one of the most dreaded of the diseases in the American tropics. A large percentage of the cases were fatal. An American army commission, headed by Dr. Walter Reed, went into Cuba. They tried in every conceivable way to transmit the disease from sick men to well men. It was all without success. Then Dr. Lazear, of the Commission, allowed a mosquito to bite him while he was attending a yellow fever patient. Within a few days he developed the disease and died. Thus was it proved, in 1900, that yellow fever can be spread only through the bite of a certain species of mosquito.

Courtesy Amer. Mus. Nat. Hist.

FIG. 214.—CAMP LAZEAR, CUBA
Where insect transmission of yellow fever was first proved.

During part of its life the fever organism must live within the body of the mosquito. When the infected insect bites the human, the organism passes from its arthropod to its mammalian host. The discovery of that fact made it possible for the United States to go into pest-ridden Panama, and by the cleaning up of mosquito breeding places rid the region of yellow fever. Otherwise, the Panama Canal could not have been built by human labor. Through more recent work on mosquito control, the disease has nearly been exterminated from parts of both North and South America.

Mosquitoes and Malaria.—Malarias of several different sorts occur widely over the world, and all of them are dependent upon mosquitoes as intermediate hosts. This was first proved in 1898. The discoverer of this fact, Major Ronald Ross of the British Army in India, deserves credit as one of the greatest benefactors of man; for malaria, although often not fatal, is always ruinous to human health and activity. Many regions in Italy have met military, political, and economic disaster time and again in history, and this may be directly blamed on the prevalence of malaria in that country. Under the name of chills and fever, or of intermittent fever, it was the thing that prevented the earlier settlement of many swampy parts of the Middle West, and it is still a serious affliction in most of the lower Mississippi Valley, along the Gulf Coast, in Georgia and Florida, and in the San Joaquin Valley of California. It is so common that it is not popularly dreaded as many less serious diseases are dreaded. It is estimated that the annual cost of malaria to the United States is $100,000,000 and some five thousand lives.

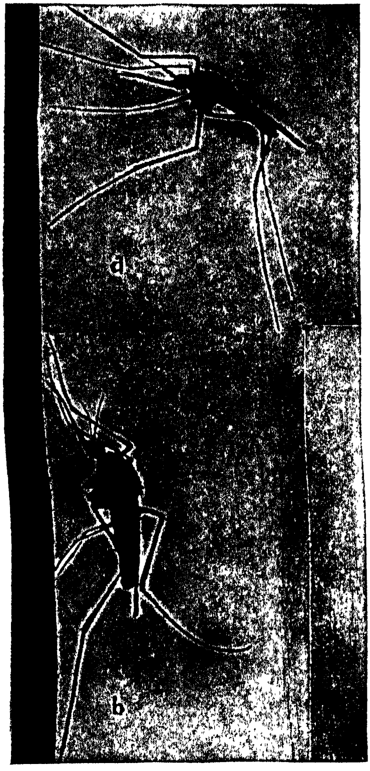


Courtesy U. S. Bur. Entomology

FIG. 215.—YELLOW FEVER MOSQUITO, FEMALE

The banded legs and silver stripes on the thorax identify this disease carrier.

Only certain species of mosquitoes of the genus *Anopheles* are capable of transmitting malaria, and consequently everyone should know how to recognize these insects (see Fig 216). The control methods are evident: all standing water, abiding places of the larval mosquitoes, must be abolished. This involves an eradication of all stagnant ponds, sluggish ditches, meadows, marshes, woodland pools, open cisterns, cesspools, barrels and tubs about the farmyard, sewer catch basins in the city, and of all stray tin cans in which rain water may stand for the ten days necessary for mosquito development. If the people of any community will, as a community, set themselves to performing this clean-up, they can be free of most of their malaria, and of other mosquito nuisances as well.



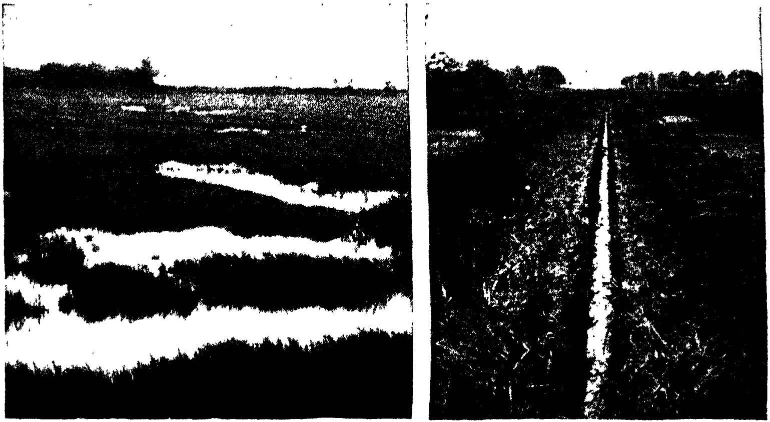
From Herms' Medical Entomology
Courtesy Macmillan Co.

FIG. 216.—MALARIA (a) AND RAIN-BARREL (b) MOSQUITOES
Showing characteristic attitudes, serving to distinguish the disease carrier.

Other Diseases.—Numerous severe diseases of the tropics are insect-borne. The devastating sleeping sickness, which has made whole regions of Africa uninhabitable, is spread by the tsetse fly. Many different tropic fevers depend on insects. We have described only the most important of our American insect-borne diseases. We now know that insects may transmit the organisms of over 250 of the diseases of man and of the domestic animals. Insects thus appear responsible for many, perhaps for a half of all cases of germ diseases; and our knowledge is still incomplete.

Heroes of Science

The physicians, bacteriologists, and entomologists who are studying these diseases engage with things more deadly than bullets. Bullets and human enemies may be seen, but disease organisms are sometimes studied for decades before they are discovered. Science has as its most brilliant pages the stories



Courtesy Conn. Agric. Exp. Sta.

FIG. 217—BEFORE AND AFTER: MOSQUITO CONTROL

Disease controlled by draining the breeding places of the insects.

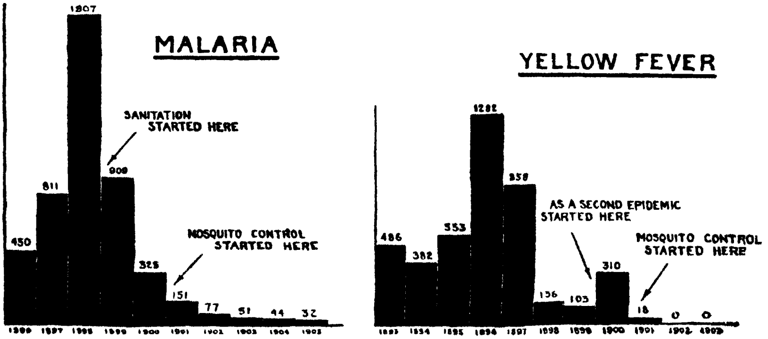
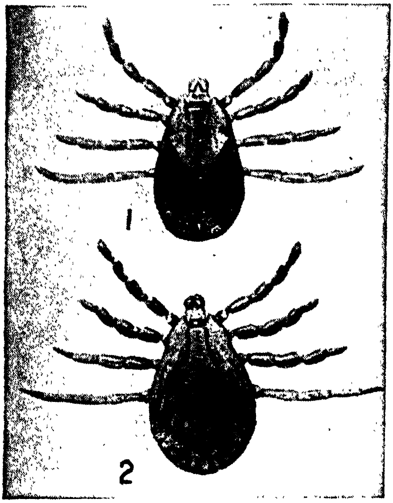


FIG. 218.—DEATHS IN HAVANA, CUBA

Showing the value of mosquito control.

of the sacrifices made by the investigators of human disease. Repeatedly these men have submitted to infection, and have contracted diseases in their most severe forms in order that our knowledge might be bettered.

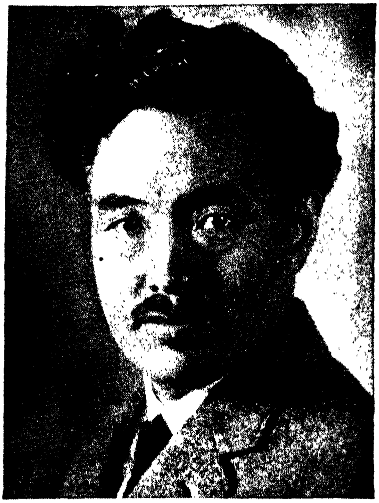
In the investigation of trench fever, in 1918, several entomologists deliberately harbored lice on their bodies in order to study the life histories of the suspected insects. Meanwhile, sixty-six men of the American army in France offered themselves for experimental work. Thirty-nine of them contracted trench fever, with its weeks of illness and great suffering. Incidentally, the hospital in which the experiments were carried out was shelled by enemy bombs.



Courtesy U. S. Bur. Entomology

FIG. 219.—THE TICK THAT DISTRIBUTES ROCKY MOUNTAIN SPOTTED FEVER

(1) The female, (2) the male.



Courtesy Rockefeller Institute

FIG. 220.—HIDEYO NOGUCHI, 1876-1928

The Japanese bacteriologist whose brilliant studies have contributed to our mastery of many diseases.

It is no mean thing that such volunteers are doing. Repeatedly it has cost the lives of the investigators. One of Pasteur's assistants, Thuillier, fell victim to cholera in Egypt, early in the studies of that disease. The investigations on yellow fever accounted for four deaths and the life-long incapacitation of several other investigators. In the study of Rocky Mountain spotted fever six or more investigators have given their lives. Ricketts, the brilliant student of so many germ diseases, studied typhus in order to learn more about tick fever, and died of typhus in Mexico. Russia had previously contributed one of her workers, Prowazek, in the study of the same louse-borne disease. Several German, American, and English physicians fell victims to typhus during the World War. Noguchi, the Japanese whose labors in our own country rank him with the best of the bacteriologists, contracted yellow fever and died while pursuing the study of that disease in Africa. These men, and many others, are heroes who went into their work with a full knowledge of the deadly nature of the tools they were to employ.

While the only sacrifice we are asked to make is the application of our knowledge to the control of these human diseases!

SUMMARY

1. For ages it has been believed that diseases are distributed by the air. The recent findings are that many bacteria, including bacteria of decay, are so distributed, but that few disease organisms can survive the light and drying out of an air journey.
2. Consequently patients with contagious diseases may be cared for without danger to the nurse if she stays an arm's length away, or if she takes precautions to use germicides whenever actual contacts have to be made.
3. Most disease germs are transferred from victim to victim by direct contact. Diseases whose germs may thus be acquired are spoken of as contagious diseases. You should know which of the commoner diseases are contagious.
4. Most of the disease germs enter through the mouth. The unbroken skin is fairly germ-proof, but all breaks in the skin need treatment with some germicide. Few infections occur by way of the respiratory tract unless it is injured in some way. The cleansing of all materials and things that may reach our mouths is therefore a prime means of controlling disease.

5. Insects and some arachnids serve as carriers for many disease germs with which we would not otherwise have direct contact. Among these mechanical carriers of disease, the roach and the house fly are of prime importance. The latter insect is particularly important in spreading typhoid bacteria.

6. Insects are also mechanical carriers of plant diseases.

7. Some insects provide the only means of transportation of disease germs. Among these necessary mechanical carriers of disease there are the rat fleas (with bubonic plague), and human lice (with typhus and trench fever).

8. In some cases the disease organism has to spend part of its life in the body of a particular insect and another part of its life in man. The intermediate hosts of human disease include the yellow-fever mosquitoes and the malarial mosquitoes, the tsetse fly, and many others in the tropics.

9. The investigators on whose work our present knowledge and control of disease is based have engaged with enemies more deadly than bullets. Many of them have lost their lives in the course of their studies. It is our privilege to apply the knowledge thus gained to the control of these diseases.

DEFINE

Miasma
Joseph Lister
Germicide
Infectious disease
Contagious disease
Mechanical carrier of disease
Necessary mechanical carrier of disease
Intermediate host of disease

PROBLEMS

1. Exactly what would you do to prevent infection by way of the air from a case of tuberculosis which was in your own home?

2. What precautions would you take to control other means of infection from the above case of tuberculosis?

3. What contagious diseases have occurred in your own family or in those of your immediate friends?

4. What insect-borne diseases have occurred in your own family or in those of your immediate friends?

5. List the important characters by means of which you would identify the following disease carriers: House fly, cockroach, bedbug, malarial mosquito, body louse.

6. How long would it take to exterminate the population of your town if it had a death rate equalling that of Serbia in April, 1915?

7. Make a list of the men who are named in this chapter as contributing to our knowledge of the transmission of disease. After each name, indicate the nationality represented. Discuss what we mean when we say that science is international.

8. Milk in the mammary glands of cows is ordinarily free of disease organisms. List the possible sources of the disease organisms that may get into milk before it is used on the table.

9. Pasteurized milk is milk that has been heated for half an hour at about 142° F., a temperature high enough to kill most disease germs, but still about 70° F. below the boiling temperature of water. What are the possible sources of the disease germs that are sometimes found in the pasteurized milk that reaches the table?

10. What local or state regulations protect your own milk supply?

11. How are the public swimming or wading pools in your community handled to prevent the distribution of disease?

12. Are common drinking cups still in use in any public places in your town?

13. It is an old idea that the planting of a dense growth of plants in a region will prevent malaria. Is there any possibility that this might be so? Explain.

14. List the germ diseases which are not contagious.

15. In a germicide, what are the advantages and disadvantages of those which are water solutions, compared with those which are alcoholic solutions, of the germ-killing chemical?

16. Some of the most effective germicides cannot be used in the mouth, in the nose, or on other mucous membranes. Why? (There are two reasons.) Name one or more that can be used on mucous membranes.

17. What germicides are available in every home, without purchase at the drugstore? How good are they as compared with some of the patented germicides?

18. What is the source of the drinking water supply of your community, and how is it treated to control the spread of disease?

19. What precautions should be taken to make drinking water safe when it is obtained from a well or cistern?

20. If you were planning a trip which would take you into small towns and rural communities as well as into larger cities, what precautions would you take in regard to food and drinking water?

21. Narrow-necked, earthen or skin water bottles, such as natives use in many parts of the world, and even modern canteens under some conditions are unsafe sources of drinking water. Why?

22. Is running water or still water safest for drinking?

CHAPTER XXII

IMMUNITY TO DISEASE

One of the most remarkable things known about certain of the germ diseases is the fact that a man who has survived one attack may be safe against further attacks of that same organism. He has become immune (*im-munis, not a slave,* as the Latin puts it) to that disease. Long ago primitive peoples in far corners of the world had learned this valuable fact and had made some use of it. Sometimes they would deliberately associate with disease and acquire a case, if possible a mild one, which would henceforth make them safe from further attacks.

Our modern knowledge of immunity is, however, little more than a hundred and fifty years old, dating from the very time when these United States were first forming an independent nation.

Jenner and Smallpox

The scene occurs between a milkmaid and a young boy. It is in a surgeon's office in a small town of south-central England. The boy, Edward Jenner, is about the age of the average high school boy in this (our own) day. Ever since he was thirteen he has been serving as an apprentice, studying the elements of surgery, doing the chores in this office. There is smallpox again in the community. It is the dread pestilence that has appeared regularly ever since men were first afflicted. It has claimed the lives of endless millions of all races. Paupers and princes, savage and learned, the strong and the weak, the old and the young have fallen before it. Where its victims have not succumbed, it has left pitted scars that proclaim its triumph. So few have escaped its fury that in many a town it is possible to describe a man as the one whose face is not pitted.

The boy is advising the girl to beware of the disease. She hastens to answer: "I cannot take that, for I have had cowpox." The boy is surprised at the answer. He wonders if there can be truth in it. He inquires further, and returns to his work while he ponders.

It proves to be a common belief among the dairymaids. Sometime later, Jenner submits the question to the great physician in whose London office he goes to study. The master's advice is: "Don't think, Jenner, but try it." So, still later, the young man, becoming an independent physician, back again in the country, carefully secures all the information that the country folks can give him, and carefully searches the history of every case he can follow.

It is after twenty years of such studies that, on the fourteenth of May, 1796, he ventures to take pus from a cowpox scab that has developed on the hand of Sarah Nelmes, and places it in some pricks made by a needle in the arm of eight-year-old James Phipps. This is *vaccination*. After a few weeks, the efficacy of the operation is tested when fresh matter from a severe case of smallpox is injected into the arm of the boy. His continued good health proves beyond all argument that it is possible to secure complete protection against smallpox!

Here is the promise of victory over one of the scourges!

Jenner's operation is called vaccination because it uses matter from a cow (Latin *vacca,* a cow). No one, in Jenner's day, knows just what it is that is happening. But that materials from one of the diseases, cowpox, can prevent further attacks of a more severe form of the same disease, smallpox, is now certain.

Pasteur and Anthrax

Now it is nearly a hundred years since Jenner fought smallpox. The next great victory is to come through that Frenchman who has already shown that there is no spontaneous generation, that germs come from germs, and that where live germs are excluded no live germs can develop. It is to come from this same Pasteur who has shown that diseased silkworms are diseased because of the germs in them—who, indeed, has already begun to prove to the world that other diseases may be due to germ activities.

Courtesy Amer. Mus. Nat. Hist

FIG. 221.—LOUIS PASTEUR

The problem concerns anthrax, a highly fatal disease of sheep and of other mammals. The loss from this disease is proving a great drain on the resources of France. Pasteur for some years has been trying to find a preventive or a cure. He has grown the live bacteria of anthrax in his test-tubes, but he finds that they cannot be used for vaccination. The introduction of even the smallest dose of these germs into a sheep will, without fail, start a fatal attack of the pestilence.

But now he has discovered that anthrax bacteria that have been kept at abnormally high temperatures are so weakened that they may be injected into sheep without harm, or with the development of only a slight attack from which they will recover.

But it is still in the 1880's. Pasteur's findings are being questioned. There are those who doubt that vaccination will produce immunity in all the sheep that receive it. There are others, including many of the most prominent physicians of the day, who will not believe that germs have any relation to that or to any other kind of disease. There are even some who insist that the disease rises spontaneously from the soil of the fields, from the food of the animals, from—anywhere! They ridicule all of Pasteur's theories. They invite him to produce proofs that they, with their own eyes may see; to demonstrate that vaccinated sheep are safe against the scourge of the sheepfolds. One of the leading veterinarians extends the invitation, sarcastically reminding him of the glory that will be his if he can prove that he has not been mistaken, but warning him of the disaster which public defeat will bring him.

It is late in May, in 1881. During the month fifty sheep have been prepared for the final test. Twenty-five of them have been vaccinated. Twenty-five of them have had no vaccination. All of them are to be subjected to infection. Pasteur predicts that all the vaccinated sheep will live, that the unvaccinated will not survive it.

On the thirty-first of May any number of witnesses, some friendly, most of them hostile, are present. As the sheep are given the dose of active anthrax germs, one of the critics seizes the bottle from Pasteur's hand and violently shakes it. They fear the practise of some deception. They demand that Pasteur give the anthrax germs first to a vaccinated, then to a non-vaccinated animal. They add cows and goats to the experiment. They insist that the size of the dose be tripled.

Pasteur, indifferent to their hostility, magnificently confident of his results, follows all of their requests without seeking their motives.

Then the group adjourns with an agreement to return in forty-eight hours.

On June first several of the vaccinated sheep show some fever; one lamb is lame. The unvaccinated sheep are, however, much more burdened. They are getting worse and worse. The leading critic is forced to write in his notebook: "Breathlessness is at its maximum; the heaving of the sides is now and then interrupted by groans. If the most sick are forced to get up and walk, it is with great difficulty that they advance a few steps, their limbs being so weak and vacillating." Three of these unvaccinated animals are dead as he leaves in the evening. "Everything," he writes, "leads me to believe that a great number of sheep will succumb during the night."

Pasteur, by a sudden reaction, begins to fear for the outcome on the morrow. There is a rise in temperature in certain of his vaccinated animals. His faith staggers for a moment. The night is a sleepless one.

But now it is the morrow. As Pasteur arrives at the farmyard, at two o'clock in the afternoon, a murmur of applause arises from a throng of delegates from agricultural societies, men from the medical schools, veterinarians—representatives from the newspapers of half of all Europe. The applause bursts into loud acclaim, for there, lying side by side, are the carcasses of twenty-two of the non-vaccinated sheep. Two others are breathing their last. The one that remains will die before the morning. All of the twenty-five that were vaccinated have recovered from the slight indisposition and are contentedly grazing. The great English journalist hastens to cable to his London paper, and through it to the world: "Pasteur's experiment a stunning success."

Jenner had proved that something, he knew not what, taken from a diseased animal, could be used as a vaccine to produce immunity. Pasteur has now proved that it is the very germ of the disease which is the important thing in such a vaccine. Beyond the dramatic demonstrations with these sheep, he has opened the eyes of his most obstinate critics to the possibility of subduing other afflictions.

Pasteur and Rabies

And now, to complete our history, there is one more story we must tell. Again it is of Pasteur, this time at the age of three and sixty. Sixty-three years of struggle, victory, and grief, of ill-health, but of mastery of the things which his microscope has revealed to him.

However, there are other victories to be won.

From his earliest boyhood there has been a sore spot in his heart, as he remembers the wild cry of "mad dog" sounded down through the village streets, and the struggle of the human victims of the dread disease: the spasms, the restlessness, the shudders, the ardent thirst, the difficulty in swallowing, the convulsions, and the frenzied madness. Through all these many years he has wondered if there may be some way of saving such unfortunates, if rabies (or *hydrophobia* as it is often labelled) may not be due to another of these bacteria, and if the principle of vaccination may not be extended to include those who have faced the mad animal.

During all his other studies, even during the days of the great anthrax experiment, he has been trying to devise ways and means of growing this mad-dog germ in his laboratory. It is a particularly difficult organism. The microscope has failed to show it. The deadly poison will not develop in the test-tubes.

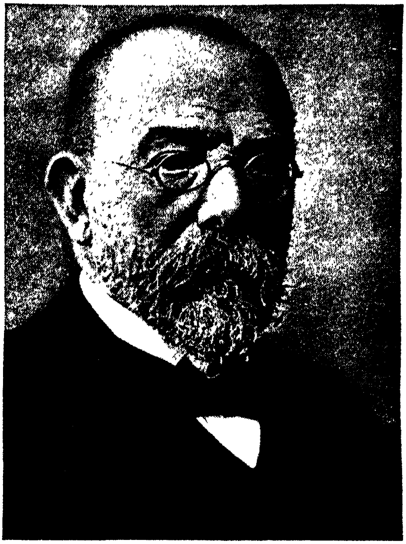

Courtesy U. S. Army Medical Museum

FIG. 222.—ROBERT KOCH, GERMAN BACTERIOLOGIST, 1843-1910

Developed the modern method of isolating single species of bacteria so they may be studied. Discovered the organisms that cause tuberculosis and Asiatic cholera. A pioneer in developing methods for the control of germ diseases.

One day, while two of the assistants hold a mad bulldog, Pasteur puts his face in front of it and sucks a few drops of the reputedly deadly saliva into a glass tube, in order that he may have virulent matter for his experiments. But still the attempt is unsuccessful.

Then a happy inspiration leads him to realize that rabies does its fatal work in the nerve tissues of its victims. Thereupon the brains of dogs and rabbits become the living test-tubes on which the dread germs at last consent to develop. One hundred generations of rabbits are sacrificed to the experiment. By this time Pasteur has obtained the poison in a form which he can use for developing a vaccine that may produce immunity.

It is a day in July, 1885. A child, Joseph Meister, from Alsace, has been brought into Pasteur's laboratory. The boy was bitten by a mad dog, two whole days ago. Going along to school, he was attacked and thrown to the ground by the animal. Too small to defend himself, the child covered his face with his hands, but the bricklayer who came to beat off the animal found the lad covered with blood and saliva. The German physician advised the mother to hasten to Paris.

Pasteur is much moved at the sight of the lad, suffering so badly that he can hardly walk. The man's friends who are physicians advise that there is little chance for the boy if some miracle does not happen. They urge that Pasteur's experiments on dogs have gone far enough to be conclusive. They insist that it is his duty to fight for the life of the youngster.

Divided between fear and hope, Pasteur selects a brain from one of his rabbits that has died of rabies. For fourteen days they have been drying this brain until the disease organisms in it have been weakened to the point where they can do no harm, but still may produce a bit of that precious immunity.

The injection of the germ-laden liquid is a slight operation. The child dries its tears when it finds that a slight prick with a needle is all they are going to do to him. Pasteur arranges a bedroom for the child and its mother in the midst of his laboratories. The boy has a glorious time with the chickens, guinea-pigs, and rabbits which are part of the scientist's experiments. Day by day they inject more infected brain of a rabbit, each time a brain that has been dried for fewer days and that is, consequently, more deadly. As the end approaches

Pasteur passes through a succession of hopes, fears, and anguish, yearning to snatch little Meister from death. He passes restless nights. He can no longer work. On the sixteenth of July, at 11 A. M., they make the final injections from the brain of a rabbit dead only one day, a dose that has been proved fatal to non-vaccinated, laboratory animals.

Courtesy Amer. Mus. Nat. Hist.

FIG. 223.—PASTEUR

With a group of children whom he has saved from the effects of rabies.

Joseph Meister now shows neither fear nor shyness. He merrily receives this inoculation. At evening, he claims a kiss from "Dear Monsieur Pasteur" and goes peacefully to bed. The scientist spends a night made horrible with insomnia.

But the days pass. The lad remains in the best of health. This time it is a human life which has been saved—by immunity acquired through vaccination.

The world pays tribute to a great master. From the far ends of Europe they come, the bitten and bleeding to receive the carefully measured doses of precious vaccine; dukes and kings to bestow fortunes for the building of Pasteur Institutes; the learned and brave to help in the further advances of science.

Thus it is that in this day, when you and I meet the dread affliction, we find near by, never too far away, some physician, some state laboratory, some other Pasteur Institute that will win the fight with these germs, if we submit to the pricks of the needle.

What Produces Immunity

What was it that was done by Jenner, Pasteur, and the others whose names we have not mentioned? How was it that they were able to produce immunity through vaccination?

The answer, as we now understand it, lies in the fact that the animal body, exposed to a germ attack, has several efficient means of fighting it.

For instance: The tip of a thorn, pushed under the skin, will bring the white corpuscles of the blood streaming to the wound, to gather around it, to destroy the foreign body and, if possible, to consume it. If they cannot destroy it, these white cells will aid in the formation of pus which will finally force out the splinter, leaving the wound clean and ready for healing.

With certain of the germ diseases, however, there is a second means by which the blood conducts its fight. As soon as the germs enter, the blood begins developing peculiar substances which we call antibodies. We poorly understand what these antibodies are, but that they are actual materials formed in the blood seems quite certain. If the invading germs are not immediately successful in killing the man they have entered, enough of these antibodies will form to destroy the germs or to prevent their further multiplication. It is then that the patient begins to recover.

But the antibodies, once formed, now remain in the blood, and so they will remain for some years, in some cases throughout a man's life-time, ever ready to destroy invading germs of that particular disease.

Each kind of antibody is capable of destroying only one kind of germ, the kind against which it (the antibody) was first developed. Only anthrax antibodies can destroy anthrax bacteria, only rabies antibodies can destroy the germs of rabies; but against its particular kind of organism the antibody is certain master.

Courtesy Eli Lilly & Co., Indianapolis

FIG. 224.—THE SOURCE OF PRECIOUS ANTIBODIES

In modern and scrupulously clean stables, these well-cared-for horses develop the diphtheria antitoxin used in controlling the disease in man.

What Jenner really did was to introduce the actual germs of a mild form of smallpox, in such a way that the disease was confined to a very small area; and yet the attack was sufficient to bring about the development of the necessary antibodies in the blood. Pasteur's operations depended upon the same principle.

Another thing to note is that both Jenner and Pasteur used germs which had had some of their strength, their ability to grow, multiply, and produce poisons, reduced through some sort of ill-treatment. Jenner took his germs from a cow in whose blood they had been fighting against antibodies. Pasteur's anthrax vaccine contained organisms which had been weakened by high temperatures. The rabies vaccine was made with bacteria from a rabbit brain that had been dried for several days. In the case of the typhoid vaccine which is now in use the bacteria are completely killed before they are used to produce immunity. Nevertheless, in all of these cases the weakened germs are still sufficient to bring about the desired results.

In a vaccine *(toxin-antitoxin)* until recently used to prevent diphtheria, a mixture was made of the poison *(toxin)* produced by the bacteria and the antibodies (here called *antitoxins)* taken from a horse which had had the disease. It is in somewhat the same way that a vaccine *(venin-antivenin)*, which is now available for counteracting the effects of the poison *(venom)* of snakes, is produced.

In the most modern form of diphtheria vaccine, called *toxoid*, the toxin of diphtheria is weakened by having formalin added to it.

Value of Vaccination

Common human diseases against which immunity through vaccination is now available are these:

Diphtheria (modern vaccine highly effective as a preventive)
Typhoid (immunity good for at least three years)
Paratyphoid (immunity good for at least three years)
Smallpox (immunity good for at least seven years)

Rabies and lockjaw (tetanus) are less common diseases from which one may now secure complete protection. The bites of poisonous snakes may be counteracted with a vaccine.

Less certain vaccines have been developed for several other diseases, including measles, whooping cough, hayfever, tuberculosis, and scarlet fever. There is, however, promise that the day will come when science will have found effective vaccines against all of these and still other diseases.

The present efficiency of vaccination against the four common diseases listed above is so great that there seems little excuse for their continued presence among men. The occurrence of one of these diseases, quite unpreventable in the past, has now become a mark of ignorance or carelessness. It is more than that, for it exposes one's family and the whole community to sorrow and suffering. We should, therefore, discuss these four diseases further.

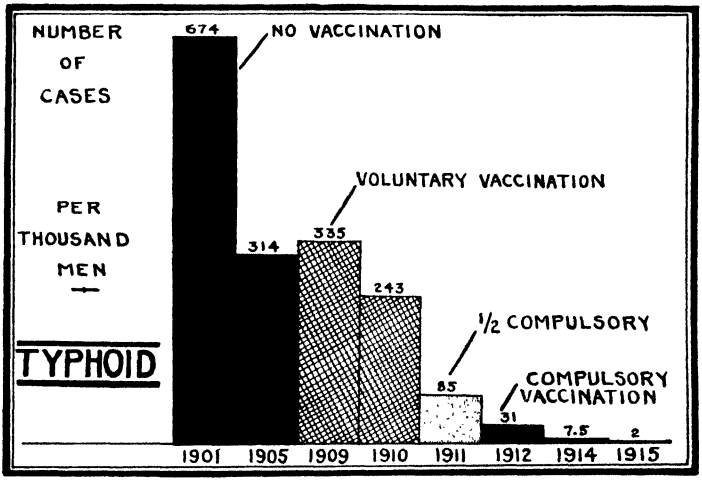


FIG. 225.—THE VALUE OF VACCINATION
The history of typhoid in the U. S. Army before and after vaccination was introduced.

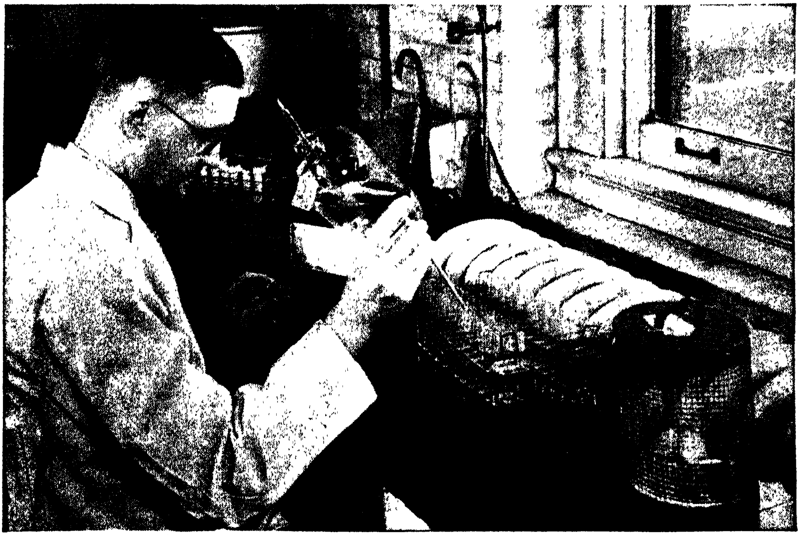
Diphtheria.—This is a serious, often fatal disease of the throat membranes. It is most common among young children. The famous Schick test, which is a ready means of testing whether a person is immune, has shown us that only 25 per cent of the children under two years of age are safe from the disease. On the other hand, 60 per cent of those over 5 years and 80 per cent of all persons over 20 years of age have become naturally immune. It is, therefore, necessary to protect younger children, and in times of epidemics to protect older persons not proven immune, by means of the vaccine which we have already described. This newly developed toxoid, if administered ahead of time, provides nearly complete protection from attack; and even after an attack has begun, the antitoxin, given within a day after the onset of the disease, is highly effective in preventing death.

Courtesy Eli Lilly & Co., Indianapolis

FIG. 226.—MANUFACTURING VACCINES: DILUTING THE STOCK TO PRECISELY PROPER STRENGTHS

Recently the small son of a European monarch came near succumbing to this disease. This but emphasizes the widespread failure to utilize the powerful armor which science has made available.

Typhoid-Paratyphoid.—These diseases of the digestive tract are still responsible for terrifically fatal epidemics among primitive peoples, in rural districts, and wherever a city water supply becomes contaminated. The germs, as we have already discovered, are distributed by way of food, milk, and drinking water, especially whenever these are exposed to the activities of house flies. In modern American cities, adequate water supplies and sewage systems have reduced the typhoid rate to nearly 1 per cent of what it formerly was, so in a city reasonable care in avoiding infection is ordinarily sufficient. The improvement, unfortunately, is not so great in rural regions. Whenever there are epidemics of this disease, or whenever one plans to do long-distance travelling, it is important to obtain immunity through vaccination.



Courtesy Eli Lilly & Co., Indianapolis

FIG. 227.—MANUFACTURING VACCINES: TESTING THE STRENGTH AND SAFETY OF THE VACCINES

The vaccine that your physician can administer contains two kinds of paratyphoid besides typhoid bacteria. The three germs produce much the same kind of disease, and immunity needs to be had against all of them. Usually the vaccine is given in three doses, each a week after the other, the first dose half as powerful as the others. The immunity thus acquired is good for two or three years and must then be renewed if one is likely to be exposed again.

As I write this paragraph, I am recovering from an attack of this very disease. Years ago, as a small child, I spent nine long weeks in bed with that affliction. I have known something of the delirium, the long fight with failing strength, the full years that were required for the recovery. My present attack of typhoid began this morning. It was deliberately and consciously stirred into me with the point of the surgeon's needle. We are insuring ourselves against all of the germs that long journeys, into strange mountains, bug-hunting in the back-country of Mexico, may bring unto us. For a few hours my arm has pained me, and I have felt exhausted. But already, this evening, I find myself better. I anticipate that, on the morrow, I shall be nearly through with this attack of the fever.

Courtesy Eli Lilly & Co., Indianapolis

FIG. 228.—MANUFACTURING VACCINES: FILLING CONTAINERS UNDER STRICTLY ASEPTIC CONDITIONS

I, who have known both methods of having it, assure you that it is a miracle, nothing but a miracle, which makes it possible to develop the precious antibodies with such slight effort.

Smallpox.—If one could finish this chapter with a record of the conquest of all of these diseases against whose attacks science has developed the sufficient armor, it would make the logical conclusion to our story. But folks, human natures, have not willed it that way.

Courtesy Eli Lilly & Co., Indianapolis

FIG. 229.—MANUFACTURING VACCINES: THE FINISHED PRODUCTS STORED IN THE CHILL ROOM

The means of exterminating smallpox have been known since 1796. The experience of nearly a century and a half has confirmed our conclusions as to the efficacy of the treatment. There are few corners of the world in which the necessary vaccine is not available. The presumably backward continents are using it. In most of Europe the disease is in all actuality conquered. Only in India, Russia, and these United States does it remain a menace.

In our own country there are the most astounding differences in the occurrence of the disease. In states like Massachusetts, with compulsory vaccination laws that are actually enforced, the disease is almost absent. There are a thousand times as many cases, per hundred thousand of population, in some of our western states. In some of them the smallpox rate is fourteen times that of Japan.

Considering the record of other countries, it is difficult to understand why we must continue to harbor these preventable diseases.

Can you discover the arguments which are used by persons who are opposed to the use of vaccines?

What have you to say for the people who are responsible for our ranking among the nations of the world in this matter of the disease called smallpox?

SUMMARY

1. Since the days of primitive peoples, it has been known that, in the case of certain diseases, a man who had had one attack would not fall victim to another. The first attack had made him *immune* to that particular disease.
2. Edward Jenner, an English physician, discovered the modern method of producing immunity through vaccination. Just before 1800 he used germs of a mild form of smallpox (cowpox), and produced an attack of the disease which could be confined to a small part of the body, but which was still sufficient to produce immunity.
3. About 1880 Pasteur proved that it was possible to prevent anthrax by means of vaccination. This gave promise that Jenner's discovery might be applied to still other germ diseases.
4. Finally (1885) Pasteur succeeded in developing a vaccine that would prevent the development of the dread disease, rabies. The victory was so complete that world-wide support was given to the further study of the germs of disease and the means of acquiring immunity from them.
5. As we now understand it, immunity may come either through the massing of white corpuscles of the blood at the infected point, or through the development in the blood of peculiar materials that we call antibodies. The white corpuscles or antibodies have the ability to destroy

the invading germs. The antibodies may remain in the blood long after recovery from the disease, and thus give continued protection. Each kind of antibody, however, can destroy only its one kind of germ.

6. Vaccines usually consist of germs that have been weakened in their fight with antibodies in some other animal's body, or through the heating, drying, or even the actual killing of the germs. These, injected into the blood of a well person, will cause the formation of antibodies and thus produce immunity. In some cases (diphtheria toxin-antitoxin, or venin-antivenin for snakebite) the vaccine is a mixture of the poisons produced by the germ or by the snake, and of the antibodies produced by an attack in some other animal.

7. Thoroughly reliable vaccines are now available against diphtheria, typhoid-paratyphoid fevers, and smallpox. They are also available against the rarer afflictions of rabies, lockjaw, and snakebite, and against several others for which the vaccines are not yet so well developed.

8. Diphtheria immunity should be bestowed upon all young children and, in times of epidemics, upon all others which the Schick test does not show to be immune.

9. The typhoid-paratyphoid treatment should be taken by those planning journeys where they will meet varied and doubtfully safe supplies of food and drinking water. At home it need be taken only if the community does not have an adequate sewage system, or during epidemics of the disease.

10. Smallpox vaccination is the one longest known. It is very simply administered and practically a certain safeguard against the disease. It is this means of control which has practically wiped the disease out of such countries as England, Germany, Sweden, the Philippines, Porto Rico, and Japan; and in our own country from the New England states, New York, Delaware, and Maryland. It is the failure to utilize the known means of control that accounts for the fact that there are several states in this country in which there are fourteen times as many cases of smallpox as in modern Japan.

DEFINE

Immune
Immunity
Edward Jenner
Vaccination
Vaccine
Cowpox
Smallpox
Anthrax
Rabies
Antibody
Toxin
Antitoxin
Diphtheria
Toxin-antitoxin
Venin-antivenin
Typhoid
Paratyphoid

PROBLEMS

1. How does your state compare with others in its smallpox rate?

2. Against how many diseases have you been vaccinated?

3. Make a list of all the measures that the people in any town should take to control typhoid in that town.

4. What can you, as an individual, do to reduce the smallpox rate in your state?

5. Can you give the arguments which are used by persons who are opposed to the use of vaccines?

6. What can you say for the people who are responsible for our ranking among the nations of the world in regard to smallpox?

7. Some people object to *vivisection* (the use of live animals for experiment) in the investigations which biologists pursue. What have you to say on this matter? Try to obtain definite information on the question.

8. Make a list of all the germ diseases against which vaccination is now available. In each case, note whether vivisection was employed in the investigations on which our methods of control are based.

9. One human life is worth—how many lives of rabbits or guinea-pigs?

10. Find some other book that will tell you something more about the life of Jenner, Pasteur, Koch, or any of the other scientists who have contributed to the control of germ diseases. Consult the list of reference books on page 365. Report to the class.

11. When measles were first introduced into the Faroe Islands, over 6,000 of the 7,782 inhabitants contracted the disease. Show why that proportion of the population could not be reached with measles in any year in your community.

12. Why is it that diseases in plants cannot be controlled by vaccines, as they are controlled in higher animals?

13. Why is it that most of the work with vaccines has been with higher vertebrates? With which other phyla of animals might vaccines also prove effective?

14. What precautions would safeguard the nurse who was attending a case of yellow fever? smallpox? typhoid? measles? typhus? diphtheria?

15. Vaccination is very recently available against certain diseases which are not caused by germs. How is this possible? Try to find out which non-germ diseases are thus involved.

PHYSIOLOGY: REVIEW

1. Review the definitions of all words listed at the ends of Chapters XVI through XXII.

2. Review all of the summaries at the ends of these same chapters.

3. Review the problems given at the ends of these chapters.

4. Explain what is meant by each of the following statements. These are the important principles in that part of physiology which we have studied.

CHAPTER XVI. **Protoplasm.**—Physiology is the biologic science in which the functions of living organisms are studied.

All living parts of plants and animals are made of protoplasm. It is chiefly a mixture of water, C, H, O, and N compounds, and energy. There is no living material except protoplasm.

There is an infinite number of kinds of protoplasm.

Living creatures made of protoplasm differ from most dead things in having definite forms and structures, the ability to grow, the ability to reproduce, and great sensitivity.

CHAPTER XVII. **Building Foods and Protoplasm.**—Foods must consist largely of C, H, O, and N compounds.

All carbohydrate foods come into existence through the process of photosynthesis.

Fats are manufactured from carbohydrates.

The first steps in the formation of proteins are effected by the bacteria that can use the N of the air.

Minerals constitute small but important portions of plant and animal foods.

The assimilation of food cannot occur unless several kinds of vitamins are present. Of these, vitamin C (preventing scurvy) and vitamin D (preventing rickets) are those that concern us most.

CHAPTER XVIII. **Using Foods and Protoplasm.**—Foods and protoplasm are continually being destroyed by respiration, fermentation, waste, and decay. They thereby release the energy (chiefly motion and heat) that organisms use to do their work.

Enzymes, glandular secretions, and hormones are also produced by destructive metabolism, and these are indispensable aids to the good functioning of the living organism.

Among vertebrate animals, ductless glands produce powerful hormones which, distributed by the animal's blood, regulate the activities of all parts of the body with the utmost precision. The thyroid, pancreas, and adrenals are such ductless glands.

CHAPTER XIX. **Human Health.**—By the good health of any plant or animal, we refer to its ability to perform all of its processes of metabolism in the most efficient way. On our own good health depends our ability to do the most of which we are capable.

Human health depends upon temperate and regular food habits, uncontaminated food, a varied diet, plenty of water, the avoidance of poisons and drugs and of poisons from digestive wastes, vigorous respiration and excretion, regular exercise and rest, and a happy outlook on the world in which we live.

CHAPTER XX. **Disease.**—Diseases are abnormal functionings of a plant or animal. They are due to break-downs in the organs of the organism (=*organic diseases*), or to the invasion of the organism by bacteria, protozoa; microscopic worms, or other germs (=*germ diseases*).

CHAPTER XXI. **Carriers of Disease.**—Disease germs are not often spread by the air, but are commonly distributed by direct contact.

Most disease germs enter our bodies on the food or other things which reach our mouths.

Insects which are responsible for the spread of serious diseases include the roach, the house fly (typhoid), rat fleas (bubonic plague and typhus), body lice (typhus and trench fever), and mosquitoes (yellow fever and malaria).

CHAPTER XXII. **Immunity to Disease.**—Germs entering the outer defenses of the body are met by white blood corpuscles which may devour them, and by antibodies which begin forming in the blood. Each kind of antibody can destroy only the one kind of germ against which it was originally formed. The antibodies may remain in the blood for some years, making the individual immune to further attacks of that germ. Jenner first discovered how to produce immunity through vaccination, and it was Pasteur who next developed that method of control.

Complete immunity through vaccination is now available for diphtheria, typhoid-paratyphoid, smallpox, and other less common diseases.

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UNIT V

Similarities and Differences Among Plants and Animals

◆

The Biologic Science Called

GENETICS

◆

HEREDITY

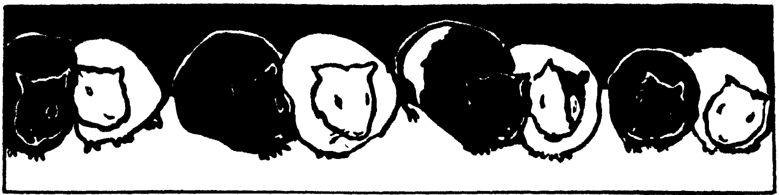
HEREDITY AND ENVIRONMENT

THE VALUE OF SCIENTIFIC RESEARCH

INDIVIDUAL VARIATION

NEW KINDS OF ORGANISMS

FOSSILS



Preview

What "family characters" do you have?

Do you show any resemblances to your father? To your mother? To your grandparents?

Why are there resemblances between parents and their children? The answer is part of genetics.

But do you differ in any way from your parents? List some of the ways. Why are there differences between parents and offspring? Are these differences, too, a matter of heredity—the result of biologic processes that run in some definite order? Or is it all a matter of chance?

How many of your characters were handed down to you by your ancestors? These are the characters which you have *inherited*. How many of your characters are the result of the things that have happened to you *since* you were born? These problems you will find discussed in our chapter on Heredity and Environment.

How much difference can there be between parents and their offspring? What is the greatest difference you have ever seen between two successive generations, in any kind of plant or animal? For instance, could a red flower give rise to one of a different color? Could a winged insect give rise to one without wings? Have such things actually been observed to happen? Could one species give rise to a new kind of plant or animal? How many such cases have actually been observed on our farms, in gardens, or in biological laboratories?

If you want the answers to these—and to other equally interesting questions—come with me in this study of genetics.

CHAPTER XXIII

HEREDITY

We have, thus far, discovered that new individuals, plant or animal, begin their lives as single cells. We have found that these single cells, the fertilized eggs, grow into many-celled organisms which are in form and functions much like all other adult individuals of that species.

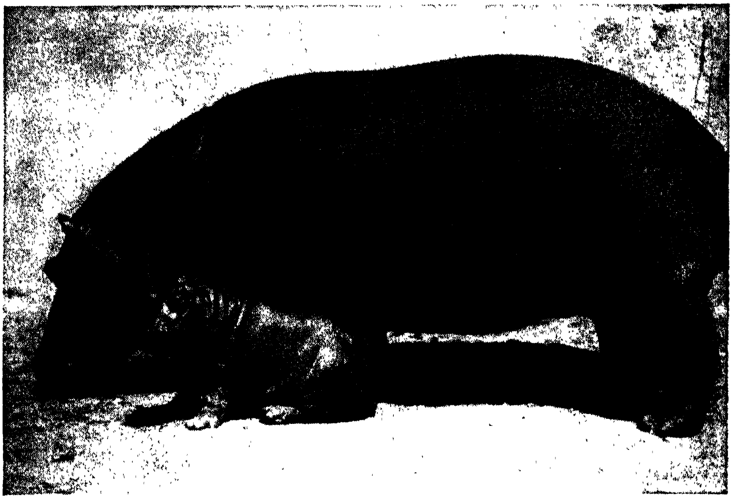
But why does each embryo grow into an adult of its own particular kind instead of into an adult of some other kind?

Why does an apple seed grow into an apple tree, while a hen's egg grows into a hen or rooster? Why does the apple seed not grow into a hen, or the hen's egg into an apple tree? Of course, such a possibility seems ridiculous! It is common knowledge that each living creature reproduces its own kind. But why is this so?

The explanation of why the offspring resembles its parents and why it differs from them as much as it does is one of the problems of the science of genetics. The processes by which the resemblances and differences are brought about are known as processes of heredity. Geneticists are also interested in the closely related question of the resemblances and differences that exist between species, and later we shall study that part of genetics also. In your grandfather's day very little was known of this science, but within the last quarter of a century, biologists have gained a considerable understanding of the orderly processes of heredity. Since all of us will meet questions of heredity in our everyday lives, it is important that everyone have some exact knowledge of this subject.

What Controls Heredity

In the first place it is evident that whatever an individual has acquired from its parents must have come to it through the two germ cells contributed by the parents, the egg and the sperm which went into the formation of the fertilized egg cell.



Courtesy Smithsonian Inst.

FIG. 230.—HEREDITY IN THE HIPPOPOTAMUS

It is, however, common knowledge that children bear resemblances to both of their parents, in some characters resembling one, in some characters resembling the other parent. The controllers of heredity must have been present, therefore, in both the egg and the sperm which formed that fertilized egg.

When the egg divided and formed a many-celled mass during embryonic development, the things that controlled heredity must also have divided and gone into every one of the new cells. They then controlled the way in which those cells formed the structures of the grown-up plant or animal. For instance, the controllers of heredity are present in the fertilized egg of a hen. As the cells of the chick embryo divide, the controllers also divide and a complete set of them goes into each and every cell of the developing bird. They are in the cells of the head, in the cells of the skin, in the cells of every other part of the body. In the head of this embryo they control the way in which the head is growing, and since they are chick controllers, they so control it that a chick head—instead of an apple tree—is the product. The controllers in the skin control that structure, and as a result it forms skin and feathers more or less like those found in the parents from which those controllers came. Similarly the controllers direct the development of every other cell so they form structures like those ordinarily found in that species.

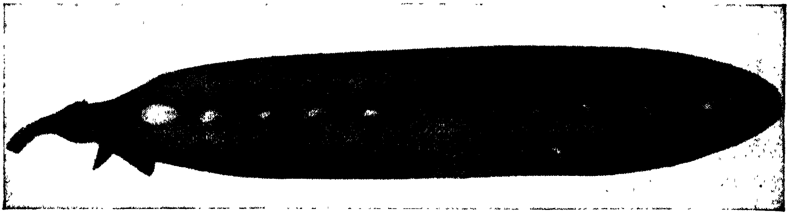


FIG. 231.—AS LIKE AS TWO PEAS IN A POD!
Because of the genes in their chromosomes.

Chromosomes.—But what are the things in the cells that thus control heredity?

It was one of the most remarkable discoveries in the history of science when biologists located those particular parts of the germ. Later we shall explain how this discovery was made, but here we may state that those microscopic things, the chromosomes which are in the nuclei of all cells, contain the structures that control the similarities and differences in heredity.

Chromosomes, let us review, are present in all cells. They are usually not visible except when they are stained with dye materials and put under a high-power microscope. The fact that they receive the dye more readily than other parts of the nucleus indicates that they are peculiar in their chemical or physical composition.

Genes.—Through indirect evidence, and more recently as a result of remarkable microscope studies, we know that each chromosome is made up of a number of parts. Each part is called a gene. The genes are the controllers of heredity.

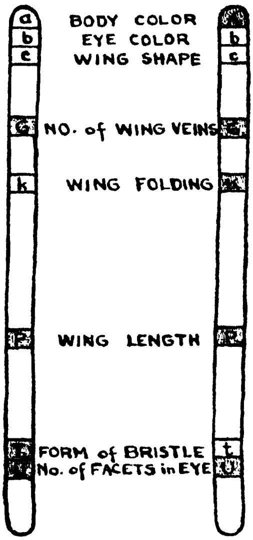


FIG. 232. — SOME GENES IN A PAIR OF CHROMOSOMES

The two genes for each unit character are in similar positions in the two chromosomes, but may be either dominant or recessive. Based on actual studies of heredity in the fruit fly.

There may be several or even scores of genes in a single chromosome. They are arranged lengthwise in the chromosome like peas in a pod. Each gene, it is now known, controls the way in which a particular character of the organism develops.

You will understand that genes are only controllers and not the characters themselves. The shape of the comb of a rooster, for instance, is determined by genes in the cells of the bird, but the comb is not in the genes in miniature. The gene is merely something that controls the way that that particular character develops. In reproduction parents pass on their genes, not their characters, to their children.

Unit Characters

It was Mendel, the first great student of heredity, who discovered that an individual is made up of many unit characters, each of which is inherited (1) independently of any other character, and (2) as a whole, never as a part.

The coat color of a guinea-pig is such a unit character, as is proved by the following: (1) The coat color may be inherited quite independently of the size of the pig, of the shape of its body, of the length of its hair, or of any other character. (2) A whole coat pattern is inherited and not a part of one pattern and part of another. The whole animal is black, or the whole animal is white, or the whole animal is covered with some other pattern. For these two reasons we speak of guinea-pig coat color as a unit character.

The unity (the *wholeness* and the *indivisibility* of a unit character) is often evident enough. The color of a man's eyes, for instance, is (with some exceptions) a single character. But the relative length of his ten fingers and ten toes is also a unit, and that is not so apparent.

Genes for Unit Characters.—There are two genes for each unit character in each of the cells of the body of an organism. There may be many millions of cells in the creature, and it will, therefore, contain twice as many millions of genes for each of its unit characters. Upon examining the chromosomes of a single cell under the microscope, one may see considerable differences in the shapes and the sizes of the various chromosomes. It is, however, sometimes possible to see that there are two chromosomes of each particular size or shape. The accompanying figures of an immature germ cell and of a fertilized egg show this condition. Since there is a double set of chromosomes, there is a double set of genes. One gene of the pair that controls a particular character (guinea-pig coat color, for instance) occurs in one chromosome, the other gene of the pair is located in the corresponding chromosome (the chromosome which is the mate of the first). If a cell should lose one chromosome of each kind, it would still have one complete set of chromosomes, and therefore one complete set of genes left.

Number of Genes in Germ Cells.—This loss of one set of chromosomes is exactly what happens in the case of most plants and animals when the germ cells become *mature*.

The young germ cells are immature eggs or sperm which are not capable of being used in reproduction. Like the other cells of the body, each immature germ cell contains a double set of genes.

But after the germ cells have been in existence for a time, they become mature. They are then capable of being used in reproduction. We say that the plant or animal in which those germ cells are located has become mature.

In the process of becoming mature each germ cell loses one of its sets of chromosomes and genes, and is left with only a single set. This difference between an immature and a mature germ cell is one which you must remember if you are to learn anything further about heredity. Study the accompanying figures of immature and mature germ cells.

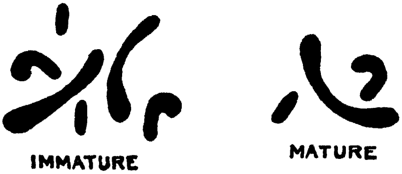


FIG. 233.—MATURE GERM CELLS HAVE ONLY ONE SET OF GENES

Number of Genes in Fertilized Eggs.—When a mature egg and a mature sperm come together during reproduction, each has but a single set of genes. But one plus one make two. One set from the father, and one set from the mother make two sets of chromosomes and genes in the fertilized egg. Thus, the new individual comes into existence with a double set of chromosomes and of genes.

Dominance

Pure-Line Heredity.—Now let us follow the history of a single gene during reproduction. Let us consider the gene for the coat color of the guinea-pig. There is a single gene for this character in the mature egg of the mother. There is similarly one gene for coat color in the mature sperm of the father. Let us suppose that these genes are alike in their ability to make the animal appear black. Call the parents P and their black genes B and B. Call the offspring the F_1 (*first filial*) generation. The mating may be pictured as follows:

Mature germs	B x B	(P generation)
When mated give	BB	(F_1 generation)

The offspring of this mating has the double dose of genes, BB, in each of its cells. Naturally, its coat will be nothing else but black. In this respect the two parents and their offspring are the same. It is a case of *pure-line heredity.* We commonly speak of such animals as belonging to a "pure breed," meaning that it is pure as far as this one character is concerned.

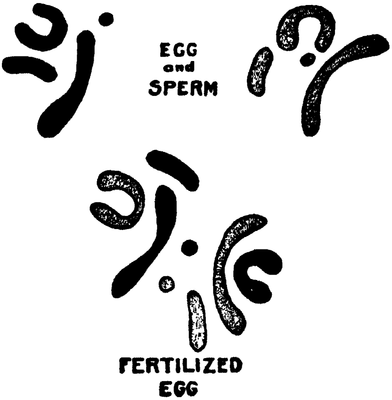


FIG. 234.—THE CHROMOSOMES IN REPRODUCTION

In the second generation, one chromosome of each pair comes from each of the parents.

Heredity of Contrasting Characters.—But let us start with two parents whose coats are different in color. Take one that is black, and one that is white. Letting B again stand for black, but letting b stand for the contrasting color, white, the story may be told as follows:

B x b (P)
Bb (F_1)

The F_1 offspring, no matter how many of them there may be, will all contain genes for both black and white. What will they look like?

Perhaps we might expect the offspring to show some color between black and white. Certainly when the black and white races intermarry the children are intermediates in color, or mulattoes as we call them. The mulatto, however, does not represent the simple case of heredity.

In the simple case, when two parents with exactly opposite (what we call *contrasting*) characters (such as B and b) are mated, all the offspring show one of the characters and little if any of the contrasting character. In the case given above, all of the Bb guinea-pigs look black. The other gene (white) is also in each of them, but it is more or less completely hidden by the black gene.

The gene whose presence shows when it is mated with its contrasting gene is said to be a *dominant* gene; the gene that is hidden is called a *recessive* gene.

The dominance or recessiveness of a particular gene is ordinarily constant and does not change. Black coats in guinea-pigs are always dominant. White coats are always recessive. Guinea-pigs that have both B and b in their cells will always look as black as though they had B and B in their cells.

If a guinea-pig has no black genes at all, and nothing but white (bb) genes, then, of course, it will look white; but then the white is still spoken of as a recessive character. Recessive characters, you see, show only when there is a double dose of the recessive gene. Dominant characters show whether there is a double or a single dose of the dominant gene.

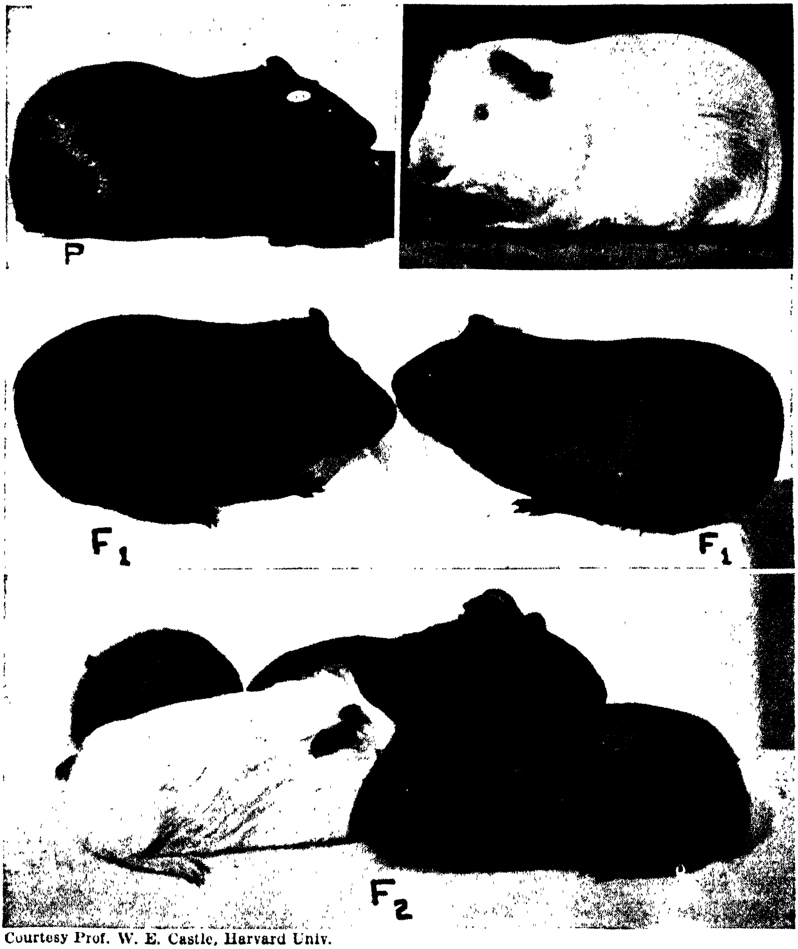
The 3 to 1 Ratio

Now let us mate two individuals from the above F_1 generation. Each of them had Bb genes in its immature germ cells. But in each individual, two kinds of mature germ cells are formed. Some of the mature cells have B genes, some of them have b genes. In mating any two of these individuals, it is wholly a matter of chance which kind of egg meets one or the other kind of sperm.

B egg with B sperm produces BB offspring
B egg with b sperm produces Bb offspring
b egg with B sperm produces Bb offspring
b egg with b sperm produces bb offspring

In all, there are three different kinds of offspring in the F_2 generation.

No matter how large the number of animals in this generation, one quarter of them will have BB. They are called *pure dominants,* because both of their genes are dominant genes. Two quarters will have Bb. They are called *hybrids* because they are combinations of one dominant and one recessive gene. One quarter will have bb genes. They are *pure recessives.*

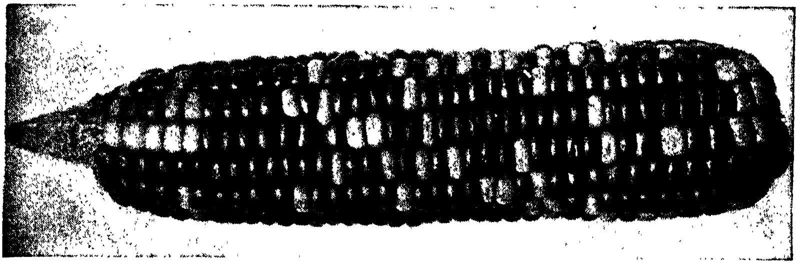


Courtesy Prof. W. E. Castle, Harvard Univ.

FIG. 235.—THE 3 TO 1 RATIO
In three successive generations of guinea pigs.

We may express it as a 1:2:1 ratio. You will get the same ratio if you flip two coins and keep a record of the number of times that two heads fall together, that heads and tails fall together, and that two tails fall together. The way in which contrasting characters are paired in the formation of the F_2 generation is as much a matter of chance as the way in which your coins arrange themselves.

But it should be remembered that in heredity the BB and Bb individuals look alike because they all have the dominant B gene. In the 1:2:1 ratio given above, the first individual (BB) and the next two individuals (Bb) look black, and only one looks white. The 1:2:1 ratio in regard to the genes, becomes a 3:1 ratio in regard to the characters.



Courtesy Profs. Babcock and Clausen, and McGraw-Hill Book Co.

FIG. 236.—THE 3 TO 1 RATIO IN CORN

What colors were the grandparents? Which is the dominant color? How can you tell? Count the grains in a row, and on the whole ear. Do you find a 3 to 1 ratio?

Ratios Are Averages.—Of course, these exact ratios do not appear in each successive four of the offspring. Neither must they be expected with the first four. The 3:1 ratio is merely an average of results when large numbers of individuals are considered. For instance, in one case the following ratios were obtained when smooth and wrinkled varieties of corn were crossed. Smooth is the dominant and wrinkled the recessive character.

Ratio of 2.4 : 1 when 48 grains were counted
Ratio of 2.7 : 1 when 174 grains were counted
Ratio of 2.8 : 1 when 2,282 grains were counted
Ratio of 3.0 : 1 when 7,072 grains were counted

Because the 3:1 ratio is only an average from large numbers, it is hardly to be expected that it would ever apply exactly to man. The human has too few offspring in any single generation to show anything like averages for heredity. Nevertheless, even here the chances in the long run are the same as with any other organism, for the laws of heredity apply to man as well as to other organisms.

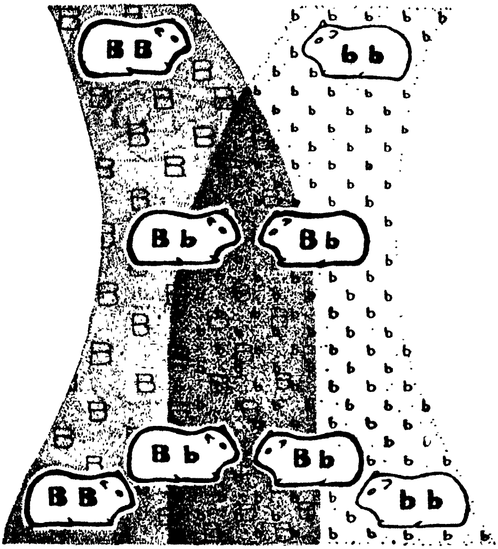


FIG. 237.—IN HYBRIDS, TWO STREAMS OF HEREDITY ARE BLENDED

The hybrids receive genes from both sides; pure dominants and pure recessives receive genes from only one side.

The abbreviated picture of what we have thus far learned about the heredity of guinea-pig coat color is this:

B x b (P)
Bb (F_1)
1 BB 2 Bb 1 bb (F_2)

If each of these F_2 individuals be mated with one exactly like itself, no new combination will develop, and so we need not carry our study of heredity beyond that generation.

Recessive Genes in Hybrids.—As a matter of fact, the most surprising thing about heredity develops when a hybrid, Bb, is mated with another hybrid individual. Both parents are black, but they produce, among others, some offspring that are white. If we did not know how heredity works, this result would seem very strange.

It is evident that the recessive genes of a hybrid are things to be considered. If recessive genes ever get into a hereditary line, they are likely to appear in some later generation. That is all right where there is no objection to the recessive character. There is none to the recessive blue of a human eye, for instance. But when the recessive character is dangerous, then precautions should be taken to avoid the mating of two hybrids, for that might give rise to a pure recessive individual of undesirable qualities.

For instance, some forms of insanity in the human appear to be connected with certain recessive genes. The members of families which have ever had those genes are likely to be carrying them now, even though they may appear perfectly normal. If such individuals mate with individuals that are similarly hybrids for this character, they will sooner or later have feebleminded descendants.

Heredity in Other Organisms

What we have said about the heredity of guinea-pig coat color applies, of course, to the heredity of other unit characters. The table lists a few of the many things that are known to behave in much the same way as this coat color.

There are many other problems of heredity that are too difficult for us to consider here, and until you study a great deal more in this science there will seem to be exceptions to the rules. Nevertheless, the further geneticists have gone in

CHAPTER XXIV

HEREDITY AND ENVIRONMENT

Is a man of good heredity certain to find success? Can a man with poor heredity ever amount to much? To what extent can inherited characters be offset by the conditions under which the man may live (the environment, as those conditions are called)? Which is more important, heredity or environment? Can we settle this age-old question?

Let us see what the scientific facts of the matter may be.

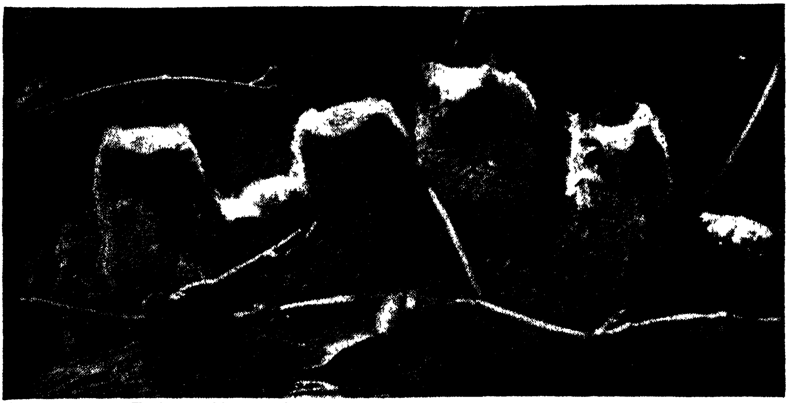
What Is Inherited

Specific Characters.—It is certain, first of all, that all specific characters, those characters by which one species is distinguished from another, are inherited. A robin is different from a potato because it has inherited, by way of its germ cells, the racial characters which the parent robins possessed. No changes in the environment could possibly make a robin become a potato, or a potato become a robin.

Among the robin's inherited, racial characters are its morphologic structures, such as the lengths and shapes of its bones, the colors and sizes and shapes of its feathers, and the structures of each of its organs. It has also inherited its physiologic characters, such as the pulse rate of its blood vessels, the normal temperature of its blood, the nature of its digestion, and the number of years it can live. It has also inherited such mental qualities as distinguish our robins from other birds: its choice of worms as food, its choice of mud to line its nest, the way it scolds when bothered by the cat, the character of its songs, etc. All of these qualities are part of a robin's heredity.

Similarly, a man is a man and not some other animal—first of all because of his heredity.

Individual Characters.—But the characters which distinguish one individual robin from the next robin, or one individual man from the next man, are also hereditary. One man will differ from the next in the color of his hair, the color of his eyes, the shape of his nose, the size of his ears, the length of his fingers, the form of his foot, and even in such a minute structure as a cataract that may be on the lens of his eye (an abnormality which weighs only one sixty-millionth part of his whole body).



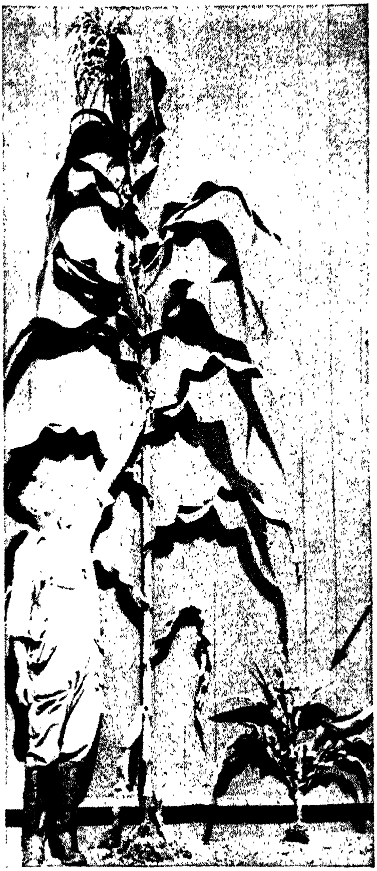
Courtesy E. W. Teale and Nature Magazine

FIG. 238.—QUINTUPLETS
Why are they so nearly alike?

Physiologic differences are also inherited. The fat man is fat first of all because of his inherited kind of metabolism. Similarly, eye-sight, good or poor, may depend primarily upon heredity. The man who goes bald at thirty, the next who still retains his hair at seventy, has a particular kind of heredity. One man receives a severe cut, but it quickly stops bleeding, closes up, and heals; the next has only a slight break in his skin, but he bleeds profusely and so persistently that without bandages or drugs he may be in danger of death. Investigation shows that the latter individual comes from a whole family of "bleeders." His genes make him a "bleeder."

Differences in mental qualities of individual men may also be matters of inheritance. The character of one's nervous control, the way one thinks, a good or bad memory, quickness or dullness in seeing the point of a thing, and other such characters may be influenced by the genes received from the ancestors. The calm, easy-going individual who doesn't worry about things is "phlegmatic," at least in part, because he has inherited a mind that works that way, or perhaps because he has inherited a good heart and a good digestion.

Each man comes into existence with an inheritance and with little more. The importance of heredity must never be forgotten. We only fool ourselves when we say that all men are born equal. While we may have equal rights legally, we greatly differ in our biologic equipments. There are really very few of us who have the necessary heredities to make good Presidents of the United States.



Courtesy P. C. Mangelsdorf and Nature Magazine

FIG. 239.—DIFFERENCES DUE TO HEREDITY

Planted on the same day, grown side by side in the same soil, the differences due to their different genes.

The rest of us might better put forth efforts for becoming famous along other lines. Somewhere in the long list of human occupations is the one field in which we are best equipped to succeed.

The Effect of Environment

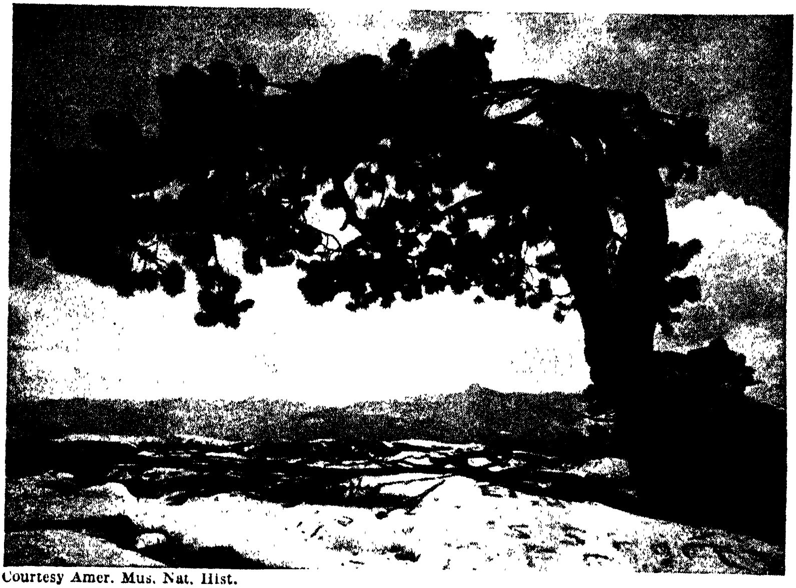
But if a man inherits all these things, is there anything about him that he hasn't inherited? What else is there to a man? Is John Jones certain to become the model of proper behavior, and John Smith as certain to go to the bad? Is there any use trying to reform John Smith? Did he get poor grades in school because he wasn't born to get better ones? Is he always doomed to yield to temptations? Can there be nothing but tragedy in his life? These are important questions. It is worth knowing something about the science that can give information on such matters.

Courtesy U. S. Bur. Animal Industry

FIG. 240.—DIFFERENCES DUE TO HEREDITY

Valuable and poor breeds within a single species.

Now, of course, it is perfectly apparent that a man is something else than what he inherits. Opportunities or drawbacks, the chance for an education or the lack of an education, good or bad companions, a poverty-striken home or a happy one with normal advantages, all of these things which we call environment, the conditions which surround us, help determine what we become after we are born.



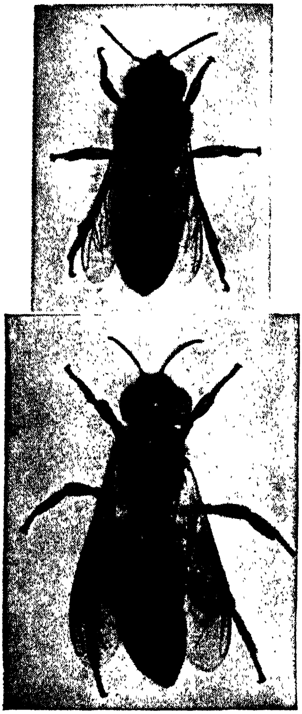
Courtesy Amer. Mus. Nat. Hist.

FIG. 241.—BENT BY THE WINDS
Shaped by its environment.

The very existence of any organism depends upon environmental factors. Some of them help; others would destroy. The weeds in front of the farmer's plough are killed by their environment, not by their genes.

The prosperity of the individual that survives is due to environmental friends or enemies. A tree that is hacked by somebody's knife becomes infested with insects or fungi, and the poor apples which ripen on such a tree are determined more by their environmental misfortunes than by their genes.

What food an organism receives may determine what it becomes. This is illustrated by the case of the queen and the worker honeybees. Both forms are females. They have the same heredities. They come from identical eggs. The adult queen is large, with a slender abdomen; she cannot make honey, she lacks hairs and other special structures for gathering pollen from flowers, and she will spend her life in the dark of the hive laying eggs. The workers are smaller, they have stouter abdomens, are able to make wax, and have several special structures for gathering pollen; they cannot lay eggs, and they will spend their time in the sunshine gathering nectar and in the hive building the comb, storing the honey, and feeding the young bees. These remarkable differences are dependent (as far as we know) upon the fact that young queen larvæ are reared in larger cells and fed entirely upon bee-jelly from the mouths of the nurse bees, while the workers are fed upon bee-jelly, pollen, and nectar.



Courtesy A. I. Root Co., Medina, Ohio

FIG. 242. — THE SAME GENES, WITH DIFFERENT FOOD

Honeybees, the worker above, the queen below.

Apparently no one can amount to more than his opportunities. It is as foolish to believe that all men have equal opportunities as it is to believe that they are born equal.

Their Relative Importance

And that brings us to the final point: That neither heredity nor environment operates alone, and that neither one nor the other is the more important. It is the way in which the two are combined that makes a man. Heredity provides the equipment; environment decides how much of that equipment may be used. Without an opportunity to use it, one's heredity is worth little. The inheritance of muscles and control is not enough to make a swimmer. An ocean, lake, swimming pool, or other suitable environment must also be provided.

All of the characters which are determined first of all by the genes may be changed by environment. Sound lungs may be injured by accident or poor posture or lack of fresh air. Strong eyes may become poor through careless usage. Hereditarily dark hair may become white because of age, or nervous worry, or peroxide.

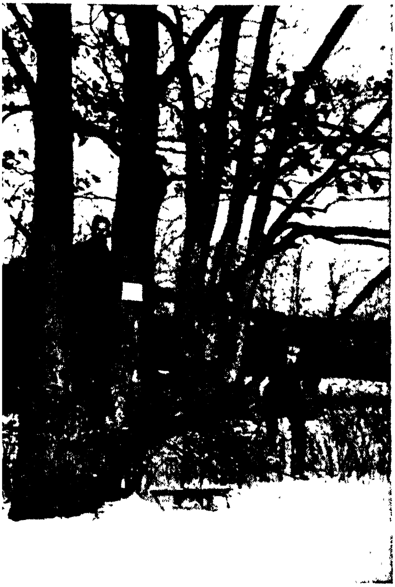


FIG. 243.—SIDE BRANCHES MAY BECOME MAIN STEMS

Explain how the environment has modified the hereditary nature of this tree.

Good inheritance is worth nothing if it is not properly preserved and *used!* Poor characters may become valuable things if they get into an environment that will help them improve. One who inherits weak lungs is not doomed to become tubercular, for good care and a healthful region in which to live may prevent all trouble. An old physician once said that he who lives longest is the one who inherits an incurable disease! This bit of exaggeration points out that good heredities are often mistreated, and that poor heredities are most often cultivated.

Probably few of us come near what we are, hereditarily, equipped to accomplish. A man is not to blame, and he deserves no credit, for his heredity. Sometimes much of his surroundings is beyond his control. But the man who deserves credit is the one who carefully chooses his environment so as to utilize the best in his hereditary equipment!

Boy and girl, get the most out of those genes!

SUMMARY

1. Can a man be anything more or less than what he has inherited? Which is the more important, heredity or environment?

2. It is well established that the characters which distinguish species are hereditary. These include morphological structures, physiologic characteristics, and mental characters.

3. We are what we are, in the first place, because of the genes we have inherited.

4. But it is certain that one's environment can affect him very much. It may kill him or let him live. It may injure or favor him. It may starve or amply nourish him. No one can amount to more than his opportunities.

5. To summarize the situation: Heredity provides the equipment, the environment determines how much of that equipment may be used.

6. No man can amount to more than he has inherited; but few of us amount to as much as we have inherited. Success consists in doing the best of which we are capable.

DEFINE

Heredity Environment

PROBLEMS

1. Find (in some reference book on heredity, eugenics, or sociology) the story of the Jukes, the Kallikaks, the Darwin, or the Edwards family, and explain how their heredities helped or hurt society.

2. Find stories of the lives of Mendel, Darwin, Aristotle (the Greek biologist), Pasteur, Abraham Lincoln, or other noted men, and show how their environments helped them to become great.

3. What are some of the chief advantages and disadvantages that we now have in our environment, but which the American colonists of about 1790 did not have in their environment?

4. Name twenty particular things in your present environment that you think are of especial help to you.

5. List the ways in which your own school environment could be improved.

6. If A has a heredity worth 100 points, and B's is worth 50 points, who makes the greater success in each of the following games of life?

A wins 25 when B wins 25
A wins 50 when B wins 25
A wins 75 when B wins 40
A wins 95 when B wins 45

7. Tell me, again! Which is more important, heredity, or environment?

8. Is there any use trying to reform John Smith?

9. Are all men created equal? Give specific instances in your answer.

10. List some of the characters of man which are very largely controlled by heredity.

11. List some of the characters of man which are more largely controlled by environment.

12. What is meant by "social inheritance"?

13. List some of the characters of man which are largely controlled by "social inheritance."

14. Are any of the human diseases inherited? Explain.

15. In an earlier chapter it was stated that body size in man depended chiefly on the hormones of the pituitary gland. Geneticists consider body size inherited. And yet it is clear that many environmental factors are involved. Name some. Then explain what determines the height of a man.

16. The hair of one individual may change from brown in youth to nearly black at maturity and white in old age. Which color was inherited?

17. Why are identical twins so important in the study of heredity and environment? From reference literature try to find some of the results of these studies.

CHAPTER XXV

THE VALUE OF SCIENTIFIC RESEARCH

Anything true is worth discovering.

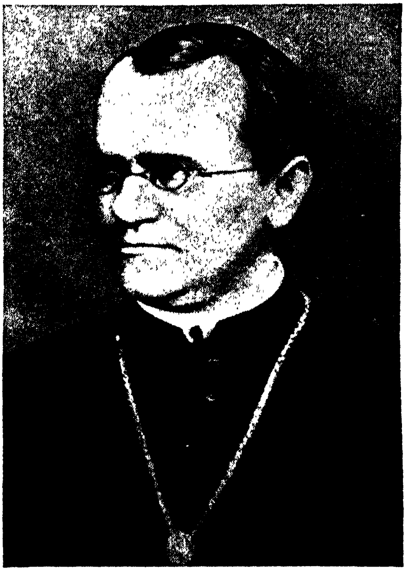
So scientists believe, and so history has proved. Much of our most valuable knowledge has come through work which, at the time, was done in order to discover truth, with no thought of a practical application.

Listen to the story of Gregor Mendel—born a poor farmer's boy in a small town of Austria, growing flowers in the garden of a monastery, dying a disappointed man who had (apparently) accomplished nothing! Then you shall listen to the tale of some biologists who discovered the most minute structures of organisms. And suddenly you will see how these labors have given us no less a worth-while thing than our knowledge of heredity.

Gregor Mendel

It was a little more than a hundred years ago, in 1822, that Gregor Johann Mendel was born in what was then Austria, within the boundaries of the present state of Czecho-Slovakia. At an early age the boy showed himself to be unusually bright, and so the farmer's family, poor as they were, decided that he should have an education beyond that which the little town afforded. It would mean sacrifice; his younger sister would have to give up part of her dowry—that bit of wealth which her parents should give her when she married. Here was the first struggle; to educate the boy, with no guarantee that he would be worth the expense, but with a fond hope that after the years were over he would have contributed to the happiness of the world!

At the higher school Johann again proved that he could think straight, and by the time he had finished there it was apparent he should go to still further studies. With that in view, he sought admission to the Augustinian house of Saint Thomas at Brno, again in Czecho-Slovakia, not a hundred miles from his old home. His duties were connected with the teaching in the institution. He was ordained as a priest when he was twenty-five years old, but then the monastery realized that he ought to study at the University of Vienna, at that time one of the chief centers of learning of the world. At the University he studied mostly mathematics and biology, a combination which, you will see, was exactly the right equipment for a student of heredity.



Courtesy Amer. Mus. Nat. Hist.

FIG. 244.—GREGOR MENDEL

After three years at the University, he returned to the Monastery where he spent the rest of his life, performing the duties of a priest, later serving as head of the institution, and incidentally growing peas in his garden. He mated the flowers of different colors, of different sizes, from plants of different heights, and of different sized and shaped pods and seeds, and he kept accurate records of the offspring of those crosses. He also watched the bees which came to his garden for nectar.

It would be interesting to know why Gregor Mendel watched those flowers and insects. Did he dream that he was going to make a great discovery? Did he ever think that he would contribute some very practical knowledge to the world? Did he hope that the heredity of the human race itself might be bettered by his discoveries? We have few records which tell us what he thought, but it seems probable that the gardener-priest labored because he liked the out-of-doors, and because he thought that if he observed carefully he would discover some truth; and that any truth was worth learning!

Courtesy Prof. G. H. Shull, Princeton Univ.

FIG. 245.—MENDEL'S GARDEN AT BRNO

The monastery garden in which the basic laws of heredity were discovered.

What did he observe? We do not know what he learned concerning the bees. His observations were never published. And all that we know about his experiments with peas was published in a single paper which he read to the natural history society at Brno. Copies of the paper were sent to various other scientists, but most of the great biologists of the day never saw it. One or two of the prominent botanists who did receive it could not understand that it amounted to much.

That, as far as Mendel knew, was the end of his years of observation. He had become head of the Monastery now, and he was involved in legal matters, opposing an unjust tax which the Austrian government had placed upon Church property. There was no time to grow peas. That had been a failure. So, it seemed, was his fight against the taxes. He died in 1884, when he was 62 years of age. But before he died he repeatedly said, hopefully, "My time will surely come."

Come, it did, but not immediately. The tax law was removed within a few years after his death. But it was sixteen years later before biologists suddenly realized the importance of his work with the peas.

Hunting Chromosomes

Now let me tell you a story, not of a man, but of a group of men who were similarly trying to find a bit of truth.

Back a couple of hundred years, indeed almost as soon as the microscope had been invented and it became possible for the human eye to see what had been invisible before, men began to search the minute, innermost structures of plants and animals. They did not know what they were looking for. They were not especially concerned with what they might find. But they wanted to learn whatever was true.

In 1835, one of the men discovered that every plant and animal is made up, not of continuous, jelly-like living stuff, but of minute cells built together into great structures.

It was found that in each of these cells there was a part which looked a bit different, and that this part, the nucleus, was really the most important thing in the cell. Many lenses were turned on nuclei, to find what they contained. A number of men were engaged in the research. But, of course, it was really only a few compared with the number of people in the whole world. Most folks didn't believe in "wasting time" looking through microscopes. The men who were studying the cells called themselves cytologists. Common folks called them fools!

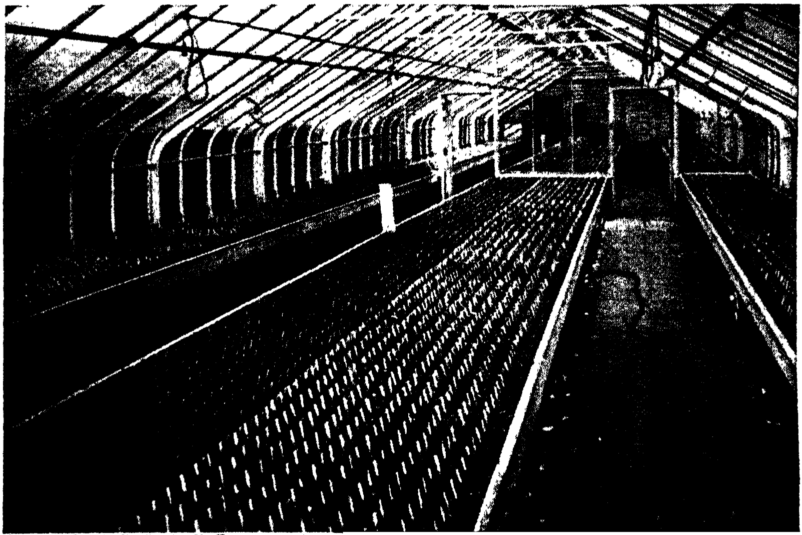
One day, 30 whole years after the cells had been recognized, someone announced that he had found that the nucleus of every cell had certain things in it—a puzzle within a puzzle, as it were. This time the discovery was the chromatin, a peculiar something which could not be seen, even through the microscope, unless it were first stained with dyestuffs. What good, what practical benefit, would a knowledge of such a structure ever do men? Nobody, not even the biologists, could answer that.

Then it took fifteen years of work before another important advance was made. In 1883 it was declared that chromatin did not always occur in broken bits scattered around the nucleus of a cell, but that at times it formed structures which were thread-like or rod-like or round like balls. The structures were named *chromosomes.*

The search which had started with the whole organism had been transferred to the cell, to the nucleus, to the chromatin, and now to the chromosomes. This time an increased army of microscopes was bent to examining the private affairs of chromosomes. How many were there? What were their shapes? Did they ever change?

It was found that chromosomes occur in all the cells of all plants and animals. It was found that all the cells of all the individuals of a species contain the same number and the same sort of chromosomes (with one exception), but that the chromosomes are different in different species of plants and animals. After long observation it was shown that the chromosomes pass directly from parents to their offspring, and that each of the two parents contributes half of the total number of chromosomes in a fertilized egg. Most interesting of all, it was found that the germ cells of an adult organism contain only half as many chromosomes as the other cells of the body.

Many other curious facts were found. But what were they worth? The neighbors thought the scientists might be more practical, and even suggested that if they would stop looking through their microscopes they might perhaps make things easier for their families. Neighbors do say such things! And worst of all, the scientists couldn't satisfy themselves that they had discovered anything of importance. It had cost hard work. It had meant years of tedious labor. There had been many disappointments and failures. Had it been worth it?



Courtesy Prof. G. H. Shull, Princeton Univ.

FIG. 246.—GROWING PLANTS BY THE THOUSANDS, TO STUDY HEREDITY

The Discovery of Heredity

Nineteen hundred, the beginning of a century, and so matters stood!

And then, suddenly, came the realization of the meaning of it all. Three European biologists, working independently on heredity, rediscovered what Mendel had discovered, and at just about the same time found copies of Mendel's paper on peas. They found that he had described what he called unit characters, dominance, and a 3 to 1 ratio, and that these things applied not only to peas but to other organisms as well. For the first time it was realized that Mendel had discovered laws applicable to the heredity of all plants and animals. The foundation of all that we have learned about heredity began with Gregor Mendel's work on peas.

And then, within a few years after 1900, biologists realized that the chromosomes, and nothing but the chromosomes with their genes, are the actual structures which control heredity. Did not the chromosomes do the very things that unit characters were known to do? Mendel had told the story for unit characters. The biologists of the microscopes had told the stories of the chromosomes. The two stories were much the same. It meant that we had discovered what controls heredity.

Thereupon the cytologists set to work harder than ever before. They are still at it. They have discovered a tremendous array of facts about chromosomes, all of which facts we now know are applicable to heredity. Botanists and zoologists have repeated Mendel's experiments tens of thousands of times, using many different kinds of plants and animals. Together the scientists are establishing our knowledge, and today we may actually predict results and to some extent control heredity.

Practical Applications of Heredity

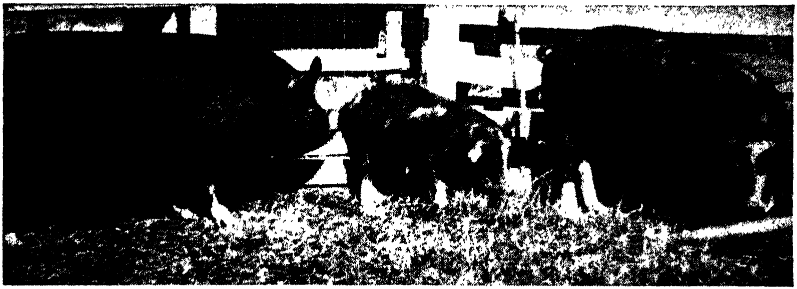
Immediately this new knowledge helped us to understand the old problem of the relative effects of heredity and environment. Our preceding chapter on that subject could not have been written before the year 1900.

We learned that hereditary characters are controlled by the germ cells and particularly by their genes. It therefore followed that things that cannot affect the germ cells of the parents cannot possibly be inherited. Deformities which the parents acquire in their lifetimes are not heritable. Tuberculosis, alcoholism, injuries to fingers or limbs cannot be inherited.

But neither are the virtues, knowledge, and wealth of our parents biologically heritable. They are beyond the genes.

We need have no hopes that they will be acquired without effort on our own part.

Mendel's discovery of dominance and recessiveness has given us a clear understanding of how it is possible for the offspring to show characters which did not appear in the parents. This had always been a perplexing problem. How, for instance, could blue eyes come from parents who possessed nothing but brown eyes? We have learned the importance of the hidden recessive genes in a hybrid individual.



Courtesy U. S. Bur. Animal Industry

FIG. 247.—RUNTS OR FINE BREEDS

Depending on whether we neglect or apply our knowledge of heredity.

We have learned that the only way to control heredity is to control the genes. We have not yet learned how to control the nature of the genes. All of our direction of the course of heredity must, therefore, come in the way in which we allow the genes to combine. We cannot control the set of genes which we possess, but in the choosing of our mates we decide what other set of genes shall be passed on to our offspring. In the care with which the genes are mated lies the best hope of an improved race of mankind.

Our knowledge of heredity has made it possible to produce new kinds of plants and animals by the mating, the crossing, or *hybridization* as we say, of different kinds of individuals. The new kinds of domesticated animals and of food and other agricultural crops that have been so produced are of dollars and cents importance. It has been possible to manufacture, as it were, improved kinds of wheat and corn and apples and pears and hens and cattle and flowers and shrubs that are much more valuable for man's use than the older varieties of plants and animals.

Men have been producing such new kinds of organisms throughout human history, but in the past it was necessary to depend upon the chance outcome of great numbers, often of many thousands of haphazard matings. Some very skillful breeders still work in this way. Luther Burbank was one who used such methods. But by utilizing the laws of heredity, more direct results may now be secured.

Take, as an example, the need of a new kind of corn in the Middle West. In the northern parts of the area, it would be desirable to have a variety which would ripen earlier and escape the damaging effects of cold autumn seasons. Incidentally, such an early corn would escape the ravages of certain of the corn insects that work harm late in the season. There are many kinds of corn, but none of them that has just the combination of other qualities which are needed on the Middle Western farm.

But send the problem to the State Agricultural Experiment Station. Describe what is needed. The biologists at the station will apply what we know about heredity, and will hybridize and re-hybridize different varieties of corn, and ultimately fill your order.

But such benefits as mankind may now derive should be credited first of all to Mendel and to the biologists of the microscopes who believed that any truth is worth discovering.

SUMMARY

1. Scientists believe that anything true is worth discovering. Much of their research is done without any idea of what practical applications may be made of their discoveries.

2. It was in this spirit that Gregor Mendel studied the characters

of the numerous generations of peas which he grew in his garden. Born a hundred years ago, in what is now Czecho-Slovakia, he served as priest and later as head of the monastery at Brno. His paper on peas attracted no attention at the time it was published.

3. Throughout those same years in which Mendel lived, other scientists, the cytologists, were studying cells. They discovered the nucleus, chromatin, and chromosomes in the cell, but had no understanding of the importance of these structures.

4. In 1900, biologists re-discovered Mendel's paper and realized that Mendel had discovered the laws of heredity for all plants and animals. Within some years it was realized that the behavior which cytologists had described for the chromosomes was the same as Mendel had described for unit characters—that the forces controlling heredity must be in those chromosomes.

5. The practical applications of these discoveries include: An understanding of the relative importance of heredity and environment. A realization that all inheritance must come through the germ cells (*i.e.*, acquired characters are not inherited). The importance of hidden recessive genes in hybrids. Emphasis on proper matings as the basis for possible improvement in the human race. More intelligent use of hybridization as a means of obtaining more useful kinds of domesticated plants and animals.

6. But the practical applications of our knowledge of heredity must be credited to the fact that there were scientists who did their research without knowing what use it might be—who believed that any truth is worth discovering.

DEFINE

Research

Cytologist

PROBLEMS

1. The statement is made in this chapter that "chromosomes do the very things that unit characters were known to do." Prove this statement.

2. Many of the facts in this biology book have no economic, dollars-and-cents value. Can you see two or three reasons why it is nevertheless worth learning them?

3. Many manufacturing establishments (the General Electric Company, for instance) hire research men who investigate things with no known applications. Why do they not restrict their staffs to practical scientists?

4. Look up the history of the discovery of one of the following: the radio, the telephone, the airplane, antiseptic (germ-proof) surgery, the steam-engine, or the methods of canning foods. Find what purely scientific discoveries had to be made before these practical applications were possible.

5. Find the name of one or more problems on which biologists are now engaged in their research.

6. Would you prefer to employ a man who was a practical man, one who was interested in research, or one who was a combination of both? Be careful of your answer. Be ready to discuss it.

7. Name as many of the applied sciences of biology as you know. (For instance, forestry is one.)

8. List some of the practical benefits which you, personally, have obtained because of the development of our knowledge of heredity.

9. Make a list of the occupations, trades, or professions in which some knowledge of heredity might prove of practical, dollars-and-cents importance.

10. Look through this book and find one instance of practical value in each of the seven units—the seven sub-sciences—of biology.

11. Which is the most important science—taxonomy, morphology, physiology, or genetics? Which of these is the most practical? If there is a difference in your two answers, explain why.

12. Biologists are now convinced that "acquired characters" are not inherited. Of what practical importance is this knowledge?

13. Why do we know less about the heredity of man than we do about the heredity of fruit flies, mice, and guinea pigs, or about corn and other plants?

14. How will we ever learn more about the heredity of man?

15. As a practical application of genetics, do we know whether it is bad for cousins (or other close relatives) to marry?

CHAPTER XXVI

INDIVIDUAL VARIATION

One cannot go far in his observation of plants and animals before he discovers that no two of them are exactly alike. Similar as the individuals of a single species may be, all individuals differ. No two robins are identical. No two daisies are the same in all the details of their structure. Not even two blades of grass are such duplicates that they cannot be told apart.

A small boy, doubting my statement, dropped onto his hands and knees and searched in the grass. Several times he came to me with similar leaves, and he seemed disappointed when I pointed out the differences in length, widths, shades of color, number of veins, and the shapes of the tips.

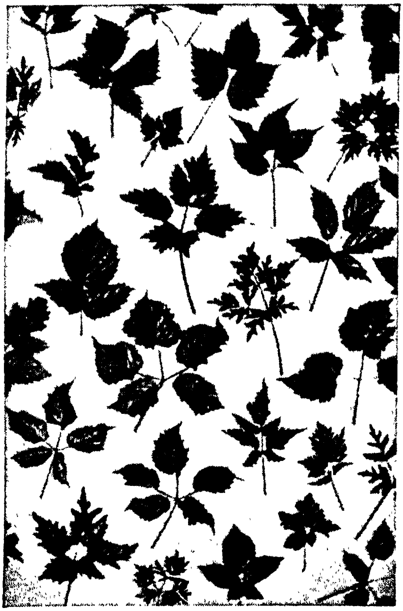
Usually such individual variation is slight, but often it is great. You are well enough acquainted with this fact, for you must have observed the great variation that occurs in the human species. Look at them! Except for identical twins, each man and woman, each boy and girl, is distinct. You are not so skilled in seeing the individual differences in other species of animals or of plants, but taxonomic studies indicate that variation in the human is no more extreme than one may find in thousands of other species.

Why do individuals differ?

Effects of Environment

Some of the differences that exist between individuals represent the direct effect of the environment on the body tissues of those individuals. Age, foods, vitamins, sunlight, moisture, temperature, poisons, exercise, disease, soap, water, peroxide—these are some of the things we have already mentioned as environmental factors capable of modifying the inherited characters of an organism.

These things affect the skin and the muscles, the digestive organs, the circulatory organs, the nervous system, the excretory system, the bones of a man. They affect all of the body tissues except the germ cells. The germ cells are so completely separated from the rest of the body that environmental influences rarely reach them. Environmental effects, therefore, cannot be inherited by the next generation. The blacksmith's son does not inherit strong arm muscles. Neither does the scholar's son inherit any of his father's knowledge.



Courtesy Luthur Burbank

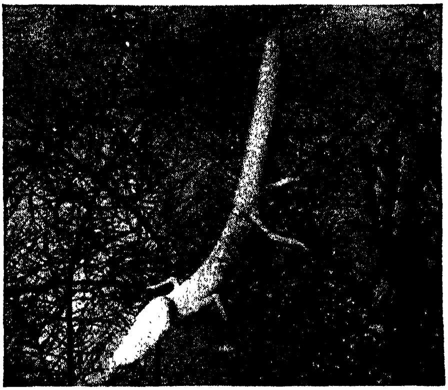
FIG. 248.—NO TWO INDIVIDUALS ARE ALIKE

Variation in blackberry leaves grown from seed of a single plant.

Lamarck's Theory.—Biologists have not always understood these limitations of environmental effects. Lamarck, a brilliant Frenchman who lived early in the 1800's, believed that such characters might, in some way, have some effect on the characters of the offspring. He thought, nevertheless, that such characters would be inherited only after many generations. Might not the tenth or hundredth continuous generation of blacksmiths be born with bigger arms? You see, one of the beauties of Lamarck's theory lay in the fact that it could neither be disproved nor proved in any short time.

Those who believed the theory insisted that we had never carried experiments far enough to prove anything.

A second important point in Lamarck's theory was his insistence that only characters that would be of direct value to the organism—of which the organism actually stood *in need*—would be inherited. He suggested that the ancestors of the present-day giraffes might have had short necks, and that the long necks came about through the habit which the animals had of reaching to the tree-tops for their food. They needed longer necks, they continually stretched the necks they did have—might it not be possible that after many hundreds of generations of such exercise giraffes would inherit longer necks?



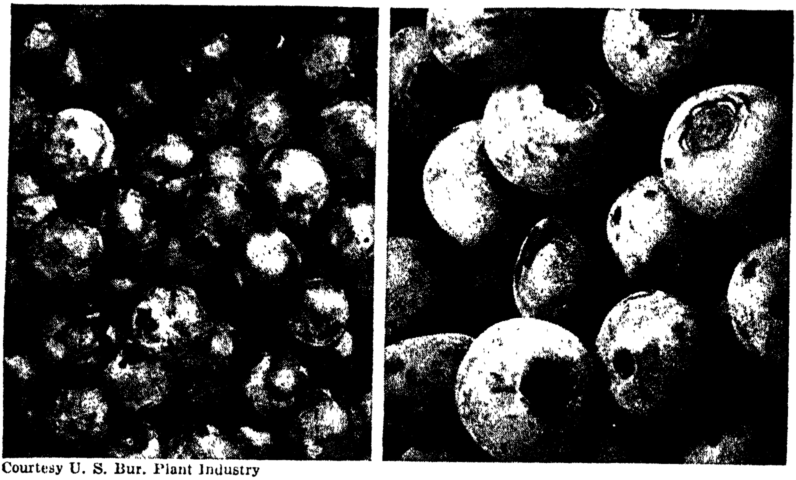
Courtesy N. Y. Zoological Soc.

FIG. 249.—TEXAN CAVE SALAMANDER

Lamarck would have said it became blind because it did not use its eyes, and lost its color because it did not need it.

Lamarck's Theory Disproved. — For one hundred and thirty years biologists have tried to find out whether Lamarck was correct. The quite positive answer which we can now give is that characters acquired by the individual within its lifetime are *not* inherited. Many experiments have been tried. Mice have had their tails cut off for endless generations, without any effect on the tails with which later generations were born. Flies kept in the dark for as many as 70 generations did not show any effect on the structures of the eyes which they had failed to use. Body mutilations have been practised by various human races for thousands of years without any effect on the inheritance of those characters. There have been many biologists who thought they had proved Lamarck correct, but none of their experiments has been verified when repeated by other scientists. The conclusion must be that acquired characters are not inherited.

None of the differences which exist between individuals as a result of the action of the environment on their body cells, will be inherited by their descendants.



Courtesy U. S. Bur. Plant Industry

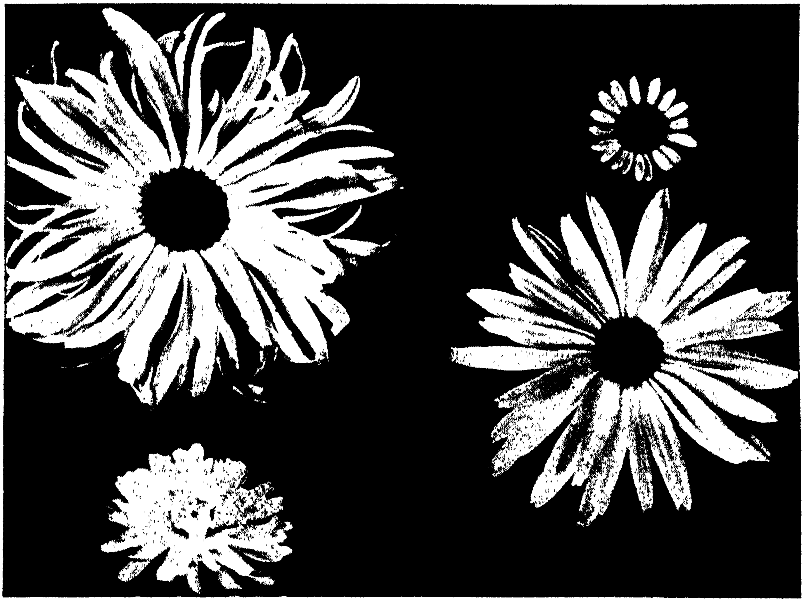
FIG. 250.—PARENTS AND HYBRID DESCENDANTS, BLUEBERRIES
Actual size! Within a decade the improved berry provided an industry for Southern New Jersey.

Hybridization

Some of the differences which we observe between individuals are, however, matters of heredity. Each individual that has arisen from a fertilized egg is a combination of the genes, of the characters, of two other individuals. He cannot look exactly like his father, nor exactly like his mother, for he is a combination of the characters of both. Pure-bred perhaps in some of his characters, he is a hybrid at least in regard to some of the others. Practically all individuals are hybrids in regard to at least some of their characters.

Each individual, then, is a brand new kind of plant or animal. It is a combination of genes, a combination of characters which has never existed before.

When the two parents are very much unlike, the hybrid offspring may be so distinct that you and I might think of them as entirely new varieties or even new species of plants or animals. Most of our new kinds of cultivated plants—flowers, shrubs, ornamental trees, fruits, field crops, and vegetables— and most of our improved varieties of domesticated animals—horses, dogs, cats, poultry, cattle, sheep, hogs, etc.—have been obtained by the hybridization of such distinct types of parents.

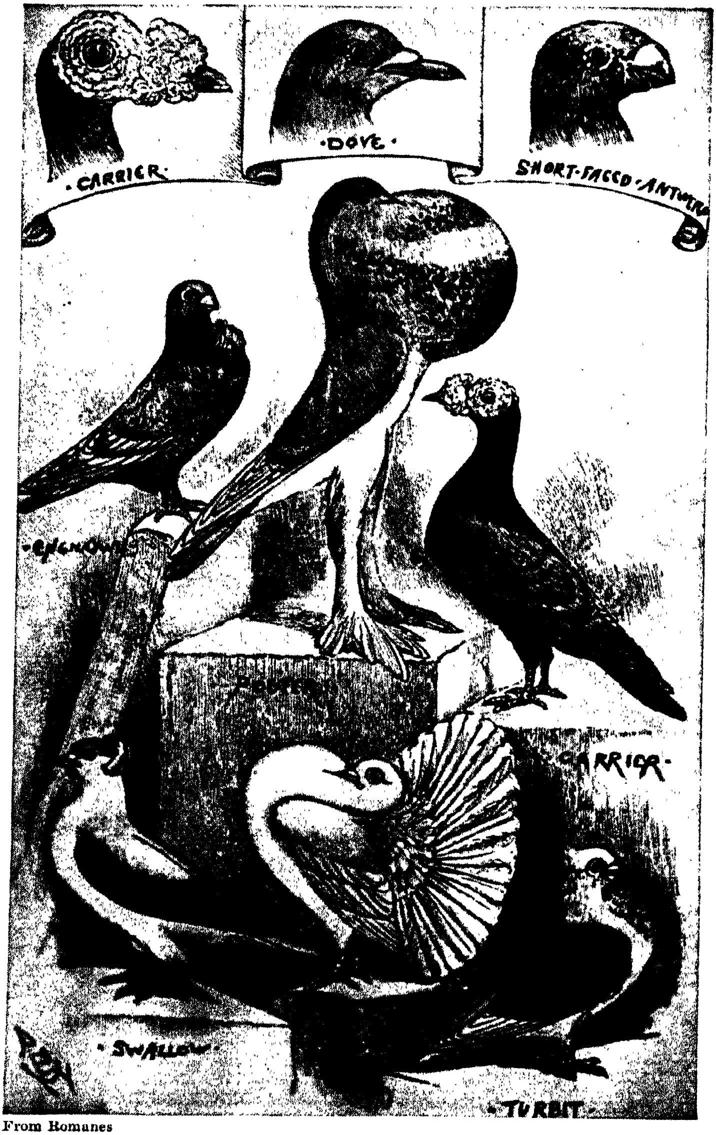


Courtesy Luthur Burbank

FIG. 251.—SHASTA DAISIES

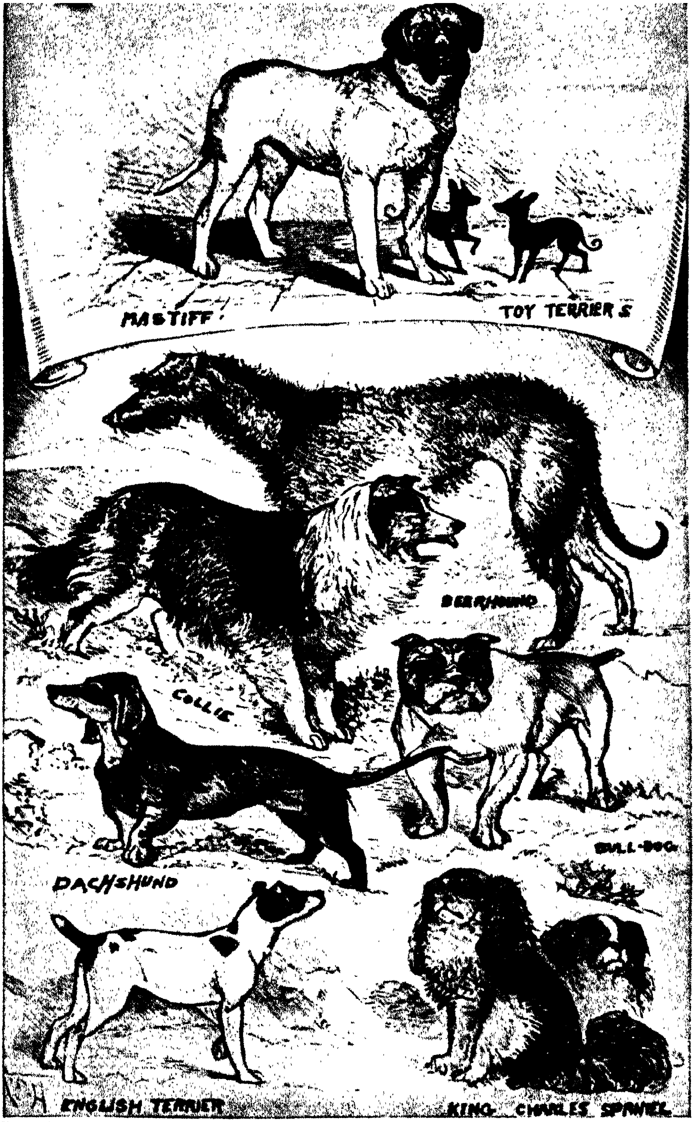
Produced by hybridization and selection. One of the original parents, the common daisy, in the upper right corner.

Hybrids among Domesticated Plants and Animals.—An original single kind of corn has given us hundreds and



From Romanes

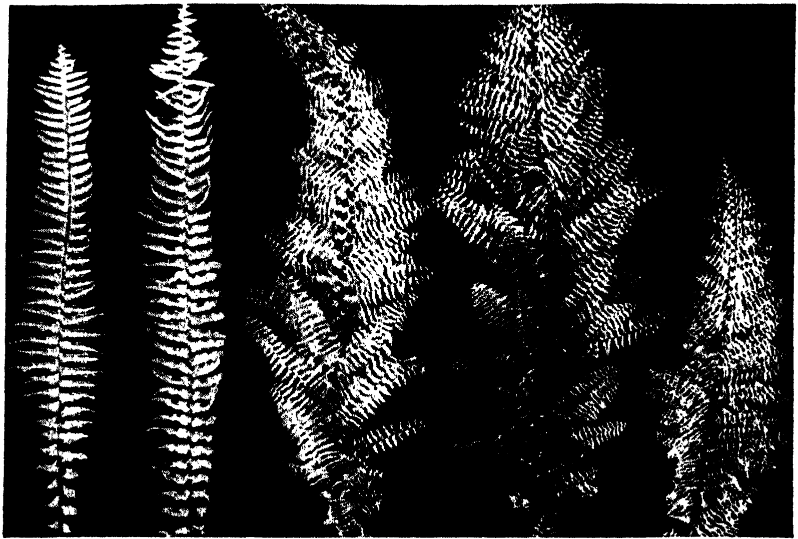
FIG. 252.—VARIETIES OF PIGEONS
Probably all descended from the Indian rock pigeon.



From Romanes

FIG. 253.—SOME KINDS OF DOGS
The result of hybridization and selection.

thousands of different kinds, many of them the result of hybridization. There are over 300 very distinct kinds of wheat, and other hundreds of less distinct varieties, most of these the hybrid descendants of a half dozen original kinds. The hundreds of different kinds of iris which may be seen in a modern garden are largely the result of the hybridization of a few original kinds of old-fashioned flag lilies. One who is not familiar with the new varieties of iris has little conception of the wealth of forms and of color combinations that have come into existence in the last twenty years.



Courtesy Brooklyn Botanic Garden

FIG. 254.—BOSTON FERN MUTATIONS
The original form at the left.

A similar story might be told of our garden tulips. Hybrid tea roses are favorites with the gardener. The famous Concord grape, originated in 1853, was one of several thousand hybrids from various other kinds of grapes. The royal walnut of California originated as a hybrid of the Eastern American black walnut and the native Californian nut. Cattle have been crossed with the American bison and with various Old World species, with the resultant production of perfectly new kinds of animals out of which agriculturists hope to find some of value on the farm.

The several different kinds of wild dogs, wolves, and jackals of various parts of the world have been hybridized and rehybridized to produce the dogs which we have today. The toy dogs, the mastiffs, shepherd dogs, Newfoundlands, St. Bernards, bird dogs, deerhounds, police dogs, bulldogs, terriers—dozens and dozens of distinct varieties—have come into existence within the last few centuries. The Newfoundland dog originated less than three hundred years ago. The bulldog was unknown before 1600, and changing fashions today are forever calling for such new kinds as the toy bulls and the Boston bulls.

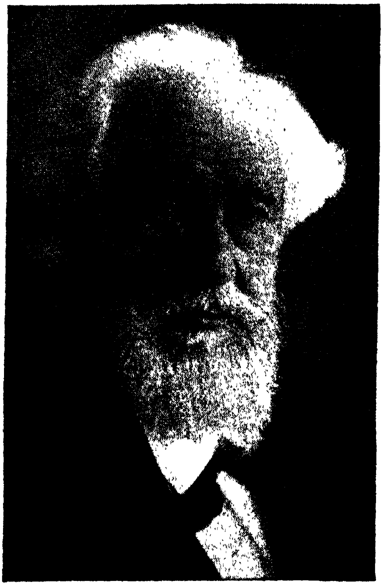
You should, by all means, go to the next poultry or agricultural show and see the new plants and animals that will be shown there.

Mutation

There is, however, another explanation for some of the differences that exist between individuals of the same species. Make all due allowance for the effect of the environment on the body cells of the individuals. Note all the hereditary traits which have been combined in the hybrid individuals. In addition to all of these we find brand new characters, totally unlike any found in any of the ancestors of these plants or animals. We know that these characters are more than skin deep, more than the effect of environment acting on the individual, for we find that these new individuals give rise to offspring that continue to show the new characters. The new characters appear to be the result of changes in the genes themselves.

Any change in hereditary characters, the result of an actual change within the genes of a plant or animal, is called a *mutation* (from the Latin *mutare,* to change). The new kind of individual is called a *mutant.*

Long laboratory study of mutations indicates that they are changes that occur quickly. Having once changed, a gene may stop mutating and remain with its new character for many generations to come. New kinds of individuals, the result of mutation, develop within a single generation and not by a series of gradual changes such as Lamarck (and, at a later time, Darwin) believed necessary before new kinds of plants and animals could come into existence.



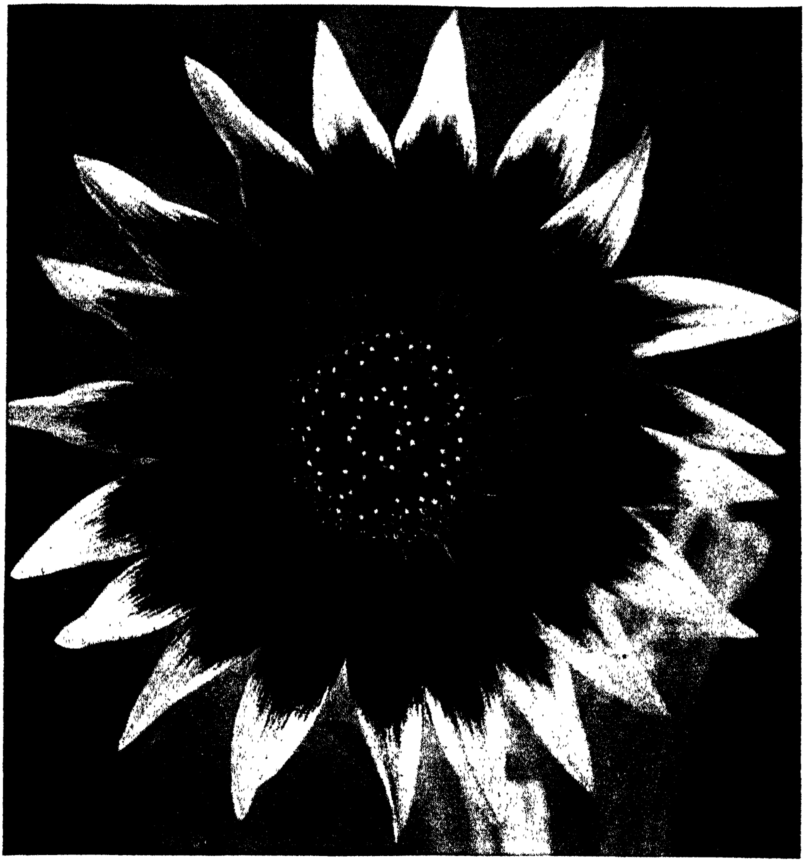
Courtesy Prof. F. M. Andrews, Indiana Univ.

FIG. 255.—HUGO DE VRIES, STUDENT OF MUTATION

The Dutch botanist (still living) whose work with evening primroses was the foundation of our knowledge of mutation.

Mutations among Domesticated Plants and Animals.—Some of the mutations that have occurred among domesticated plants and animals have been of considerable importance. In the year 1791 a New England farmer found a lamb in his flock which had short and crooked legs. With the eye of a thrifty Yankee, he saw what an advantage it would be to have a breed of sheep which could not jump fences, so he carefully took care of the freak lamb, bred from it, and got other animals with short and crooked legs. It was thus that the breed of Ancon sheep came into existence.

The Lombardy poplar, that tall and very slender tree which is commonly grown for hedges, is a mutation from the common black poplar of Italy. Among sweet peas a dozen color mutations and numerous other changes in the form and size of the flowers and of the season of bloom are known to have occurred within the last two hundred years. The Boston fern, commonest of indoor plants, arose as a mutation from a tropical



Courtesy T. D. A. Cockerell, Univ. of Colo.

FIG. 256.—MUTATION IN THE SUNFLOWER

The red mutant was crossed with its yellow parent, combining the two colors in this one flower.

species, and in the last thirty years dozens of other mutations have come from the same source. In 1912, the Connecticut Cuban tobacco, which averages 20 leaves to a plant, produced a mutation which had 72 leaves! Normally-tailed chickens have given rise to tailless varieties. Hornless cattle have arisen from ordinary, horned parents. And, to take only one more of the endless illustrations, the common old sunflower, growing almost everywhere, suddenly, in 1910 at Boulder, Colorado, produced plants with red flowers. The mutation was cultivated and has maintained its redness in subsequent generations. Clearly a new kind of plant, with an entirely new kind of heredity, had come into existence.

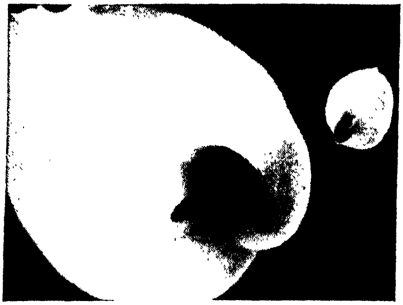

After De Vries
Courtesy Open Court Publ. Co.

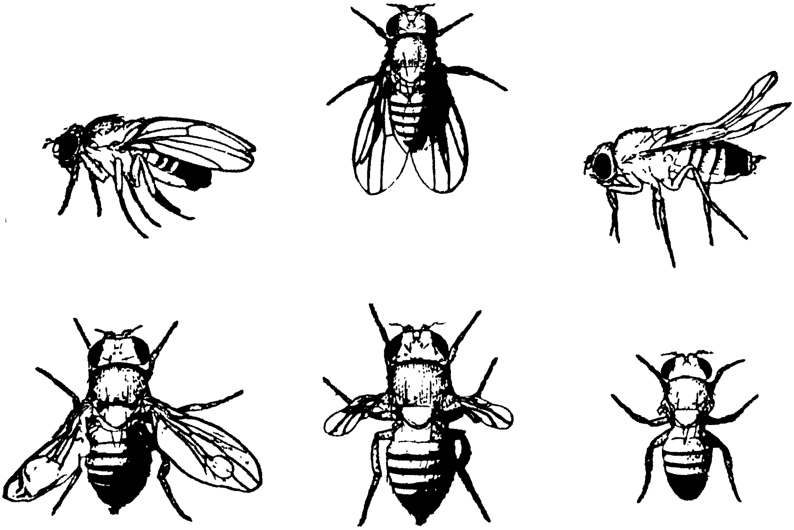
FIG. 257.—AN INSTANCE OF BACKWARD MUTATION

Burbank's dwarf calla lily, derived from the larger, more familiar form of calla.

Abundance of Mutations.—How many times have such changes been observed? The answer depends upon how large a change you are interested in. Smaller mutations probably occur in every generation. Thousands of larger mutations, large enough to attract attention, have been carefully recorded. In the last 20 years at least 400 mutations have been observed in our laboratories in that common little fruit fly which gathers about decaying fruit and about garbage cans. It is true that few changes have been observed which were greater than, say, a red from a yellow sunflower, but think how changed the present-day species of plants and animals may become through the accumulation of the mutations that are continually occurring in them.

Cause of Mutation.—Why should genes change? Ten years ago we had no answer to this question, but widespread investigations on this problem are beginning to give results. It has been found, for instance, that plants and animals which have had their germ cells exposed to X-rays produce mutant offspring more often than those not so exposed. The powerful energies released by the X-ray are able to change either the chemical composition or the physical structure of that ultramicroscopic bit of something which we call a gene.

Note that this action of X-rays on the gene is not the sort of thing that Lamarck had in mind in his theory. He thought that changes produced in the body cells could be inherited. These X-rays are affecting not body cells, but germ cells and the genes in them. Moreover, Lamarck thought that changes in species occurred only when the organism had some need of the new character. Whether the animal or plant needs the new characters has nothing to do with the effects of these X-rays.



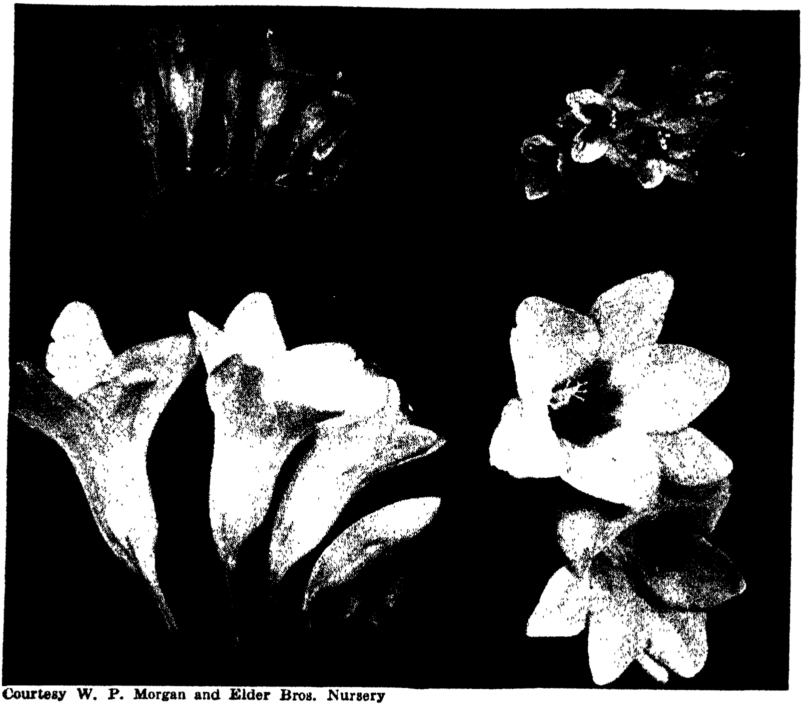
After Morgan, Courtesy Carnegie Institution

FIG. 258.—MUTATION IN THE FRUIT FLY

Six of the hundreds of mutations which have appeared in this single species in our laboratories. The topmost insect resembles the original, wild type of fruit fly.

What other factors besides X-rays can bring about changes in the genes is a thing that will have to be answered in the future. This subject is on the active frontier of biologic exploration.

After reviewing the above record, it seems strange to us when we are asked if we really believe that species change their characters and become new kinds of plants and animals. But the scientific word for any sort of change in the inherited characters of an organism is *evolution,* and there are some people who think they don't believe in evolution. The man who says so may own a new breed of dog; he wears clothing made of new kinds of cotton, or wool from an improved variety of sheep; he eats bread made of an improved wheat, and buys



Courtesy W. P. Morgan and Elder Bros. Nursery

FIG. 259.—HYBRIDIZATION AND MUTATION IN FREESIAS
The wild types above, the new horticultural forms below.

kinds of corn and potatoes and fruit and things that were unknown to his grandparents; he grows a cut-leaved, newly developed kind of beech or birch or maple on his lawn, and new varieties of roses and chrysanthemums in his garden; and he may smoke a cigar made of a very recently improved tobacco. All of these are kinds of plants which differ from their ancestors, and for which the records tell us no uncertain story of evolution.

SUMMARY

1. One of the most important things in biology is the fact that no two individuals are exactly alike. Recall how distinct each individual of the human species is. This individual variation is typical of all species of plants and animals.
2. Some of the differences between individuals are due to the effect of the environment (age, foods, sunlight, temperature, exercise, etc.) on the body cells of the plant or animal. Such things do not affect the genes in the germ cells, and hence are not inherited by the next generation.
3. Lamarck believed such environmental effects were inherited. He believed they would have to be continued through many generations, and that they would be inherited if the organism had actual need of the new character and continually exercised it. For over a hundred years attempts have been made to prove Lamarck correct, but none of the experiments has been successful. Biologists consider the theory incorrect.
4. Each individual that develops from a fertilized egg cell is a brand new kind of plant or animal. It is a hybrid of two parents, such a combination of genes as never existed before. Most of our new and improved kinds of domesticated plants and animals—thousands of kinds of flowers, shrubs, fruit trees, corn, wheat, grapes, cattle, dogs, chickens, pigeons, etc.—have come into existence through such hybridization.
5. Sometimes genes actually change, giving rise to characters which have never been found in any previous ancestor. Such new characters, called mutations, are then inherited by the next and following generations. Mutations have given rise to others of our domesticated plants and animals, and have been observed many thousands of times in laboratory plants and animals.
6. X-rays can cause mutations, but we must await further studies in order to learn what other factors can cause changes in genes.
7. The scientific term for all changes in the hereditary characters of an organism is evolution.

DEFINE

Individual variation
Environment
Lamarck's theory
Acquired characters
Hybridization
Mutation
Mutant
Evolution

PROBLEMS

1. Collect 10 leaves from the same tree. List all the characters which show variation among these leaves.

2. Make a list of 25 characters in regard to which there is variation among individuals in the human species.

3. Make a list of possible variations in human hair and skin that might be due to environmental factors.

4. Lamarck's theory is sometimes called the Theory of Use and Disuse. It is also called the Theory of the Inheritance of Acquired Characters. Explain why each name is really a good one.

5. Why do biologists object to the statement, sometimes made, that an instinct is a habit that has become inherited?

6. Have you ever seen plants or animals which were the result of hybridization? Describe some of them.

7. Of how many different breeds of dogs can you find the names? Describe three or four of the most distinct kinds.

8. Have you ever seen a new kind of plant or animal which was the result of mutation? If so, describe it.

9. Can you name some particular variety of plant or animal (other than those given in this chapter) which did not exist 100 years ago? Search for such things among the improved varieties of fruits, vegetables, flowers, grains, stock animals, pets, etc. Can you find out when and how the variety originated?

10. If you were forbidden to use any food from species of plants or animals which were not in existence a hundred years ago, what things would have been left in the three meals you had today? Conduct some investigation of this matter before you complete your answer.

CHAPTER XXVII

NEW KINDS OF ORGANISMS

We have learned that the differences which we find between individuals of any species are the result of the action of the environment on their body cells; of the hybridization of the characters of two, differing parents; or of actual changes (mutations) that have occurred in the genes.

The new characters due to environment last, at most, through the life of a single individual. They are not inherited by the next generation. But the new characters which are the result of hybridization or of mutation can be inherited by individuals of the next and the following generations. Since this is so, might we not call hybrids and mutants new kinds or new species of plants or animals?

Species Are Large Populations

The answer to our question must come from the taxonomist who has studied species as he finds them in nature. Come with me into the field. Let us collect specimens of some particular species. Since they have already been the object of my special study, we shall collect one of the gall-making wasps that occurs on oak trees.

We may collect hundreds and thousands of these insects in this locality. We shall not find any two of them alike; but all of the individuals bear a certain similarity to one another for the good and sufficient reason that there has been widespread interbreeding going on among them. Their ancestors have been "swapping" genes for endless centuries in this locality, and all of these specimens that we gather have much the same sorts of genes in them.

But let us go into new country. The insects we collect there will represent much the same variation, the endless variation which we found in the first locality. No insect of them will be quite like any other; and yet they show much the same combinations of characters which we found in the first collections.

But let us go on to a third locality, five miles or fifty miles or a hundred and fifty miles from the last. Let us continue this procedure, day after day, over the thousands of square miles which are the range of this species. We become impressed with the fact that this is a population of inconceivably great numbers of individuals that are actually all different, and yet in a very real way similar, over this tremendous territory. Of course, we can take only scant samples of this population, and we are reduced to glancing at most of the trees with their thousands of galls which we have not time to gather. We fall to wondering how many inconceivable millions of individuals of this one species are on all the trees in all the fields and woodlands and mountain forests through which we journey at many miles an hour, for hour after hour, yesterday, today, and tomorrow. Wherever we collect in this area our samples are

Photo by M. C. Dickerson
Courtesy American Mus. Nat. Hist.

FIG. 260.—SPECIES ARE LARGE POPULATIONS

surprisingly uniform. Throughout the 500,000 square miles which (we now know) constitute the range of this species, the same stock of genes has been exchanged, through endless generations, for thousands and perhaps millions of years, resulting in the uniformity which we are now discovering.

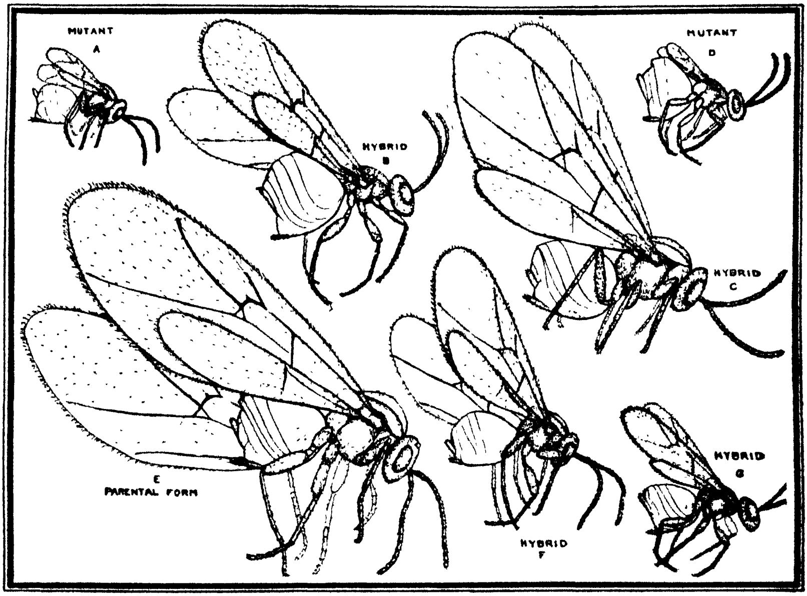


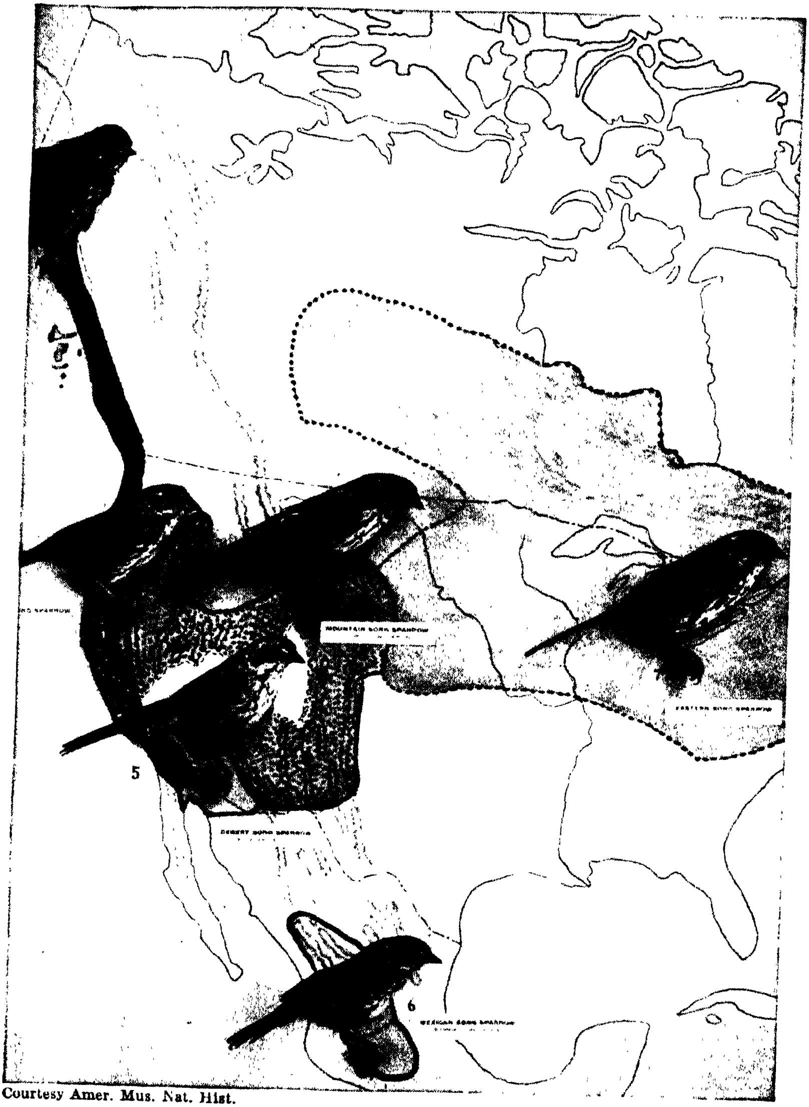
FIG. 261.—VARIATION WITHIN A SINGLE SPECIES

A Utah species of gall wasp. An extreme case of individual variation, but one that shows that mutation in nature may give rise to individuals as different as the mutants of our laboratories. The smallest individuals are, apparently, mutants from the long-winged, parental stock. Since the mutants were not isolated from the parental type, they inter-bred with it, giving rise to the hybrids (the intermediate individuals).

A species, we find, *is a tremendous population of individuals with more or less the same heredity.*

Hybrid individuals and mutants are not new species. They are individuals or small groups of individuals, not the great populations which we call species.

Hybrids or mutants may, however, as we shall see, give rise to new species.



Courtesy Amer. Mus. Nat. Hist.

FIG. 262.—DISTRIBUTION OF SIX KINDS OF SONG SPARROWS

In each region, the mutant types were able to become established species because they were isolated from the other song sparrows.

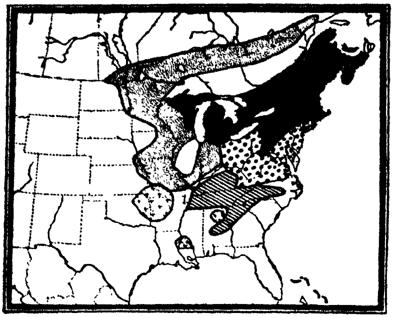
Isolation of New Species

When do such hybrids or mutants give rise to new species? In most cases these new kinds of individuals develop in places where they are surrounded by individuals of the parental type, and with them they interbreed. The offspring of such matings are all hybrids, many of them showing the new characters. Gradually, in the course of thousands of generations, the new characters are spread throughout the old species, and the old species is thus changed a bit. It becomes more variable, with some of the population showing a character or combination of characters which was not there to begin with. In that way it really is a new species, although it also retains all the characters of the old species.

But if something should happen to remove the new kind of hybrid or mutant and keep it away from the parental population, then it would breed only with individuals like itself. Thus isolated from the parental species, all of the offspring would show the new characters. None of them would have the characters of the original species. In this isolated locality there would develop a large colony of the new individuals, and in the course of time this colony might give rise to so many offspring that it would represent a population large enough to be called a species. It would be a new species.

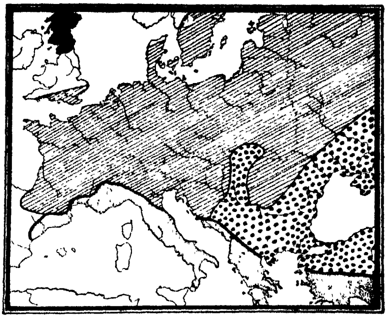
Theoretically, then, hybrids or mutants can give rise to new species only when they are isolated from the parental species. Do we, in actuality, find that new species come into existence in that fashion?

Isolation by Artificial Selection.—As a matter of fact, this isolation of new types of individuals is exactly what the breeder of domesticated plants or animals does if he desires to secure a new variety for his purposes. For hundreds and even thousands of years plant and animal breeders have had their eyes open for useful forms of mutants or hybrids which might appear. Most of the new types are destroyed because they are no better than or not so good as those we already have.



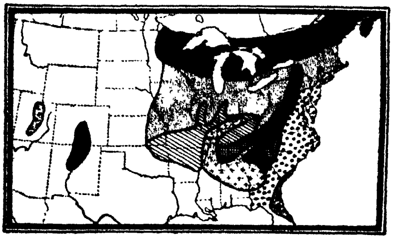
After Howell 1929

FIG. 263.—RELATED SPECIES OF CHIPMUNKS



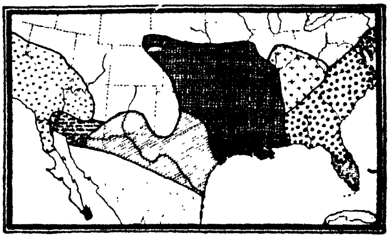
After Wettstein 1898

FIG. 264.—EUROPEAN PLANTS: EYEBRIGHTS



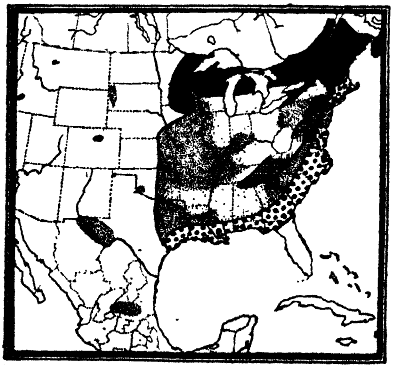
After Kinsey 1930

FIG. 265.—RELATED SPECIES OF GALL WASPS



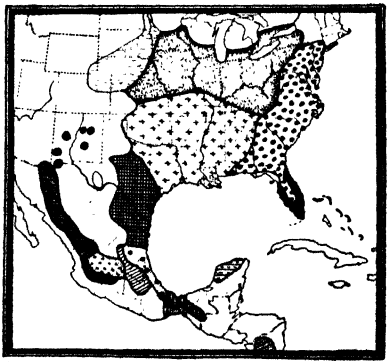
After Blanchard 1921

FIG. 266.—RELATED SPECIES OF KINGSNAKES



Data from Fernald 1932

FIG. 267.—RELATED SPECIES OF PONDWEEDS



After Nelson 1909

FIG. 268.—RELATED SPECIES OF COTTONTAIL RABBITS

RELATED SPECIES ARE ISOLATED

A few of them the breeders *select*, being careful to breed from them only.

The breeder is said to have produced a new kind of plant or animal by artificial selection. It is called artificial because it is man rather than some other force in nature that provides the necessary isolation. As a matter of fact, if it was a mutation, it was the result of a change in the genes, and the breeder had nothing to do with it. If it began as a hybrid, he may have deliberately mated the two parents. But in either case the breeder was of importance in providing the isolation which allowed a large, pure-blooded population to develop.

Isolation in Nature.—While isolation by artificial selection cannot account for new species outside of domestication, isolation through other means does occur and has occurred every time a new species has arisen in nature. We know this, because we find that every species in nature is isolated from the species to which it is most closely related. This is one of the most important facts which biologists have learned about species and their evolution.

Usually species are separated by geographic isolation. We find one kind of robin in the United States east of the Rockies. The most closely related bird is the robin of the Great Basin area and the Pacific Coast. The two are so similar that we believe they originated one from the other, or both from a common parent. They were able to develop into distinct species because each type occurred in a different region, and the two regions were separated by mountains and deserts which prevented cross-breeding between the two populations.

Similarly, it is one kind of hemlock in the northeastern United States, a distinct kind in the Southern Appalachian area, a third kind in the Pacific Northwest. It is one kind of white oak in most of the northeastern United States, another in northern Michigan, another in central Tennessee, a different one on the Gulf Coast. One kind of broad-leaved white oak occurs in Colorado and New Mexico east of the Continental Divide, another kind in those states west of the Divide, a third in the mountains of Utah, a fourth in the Black Hills of South Dakota and Wyoming, a fifth in western New Mexico and central Arizona, a sixth in the mountains of southeastern New Mexico, etc., etc. Each of these areas is isolated from the next by deserts across which oaks cannot pass. Biologists suggest that all of these species have arisen from a single ancestral type, or from one another through mutation or hybridization. It is probable that many other kinds of these white oaks arose by mutation or hybridization, but the only ones that survived were those which, by some means or other, spread into new territories in which they were isolated from the parental species.

The figures on page 426 show several other cases of geographic isolation.

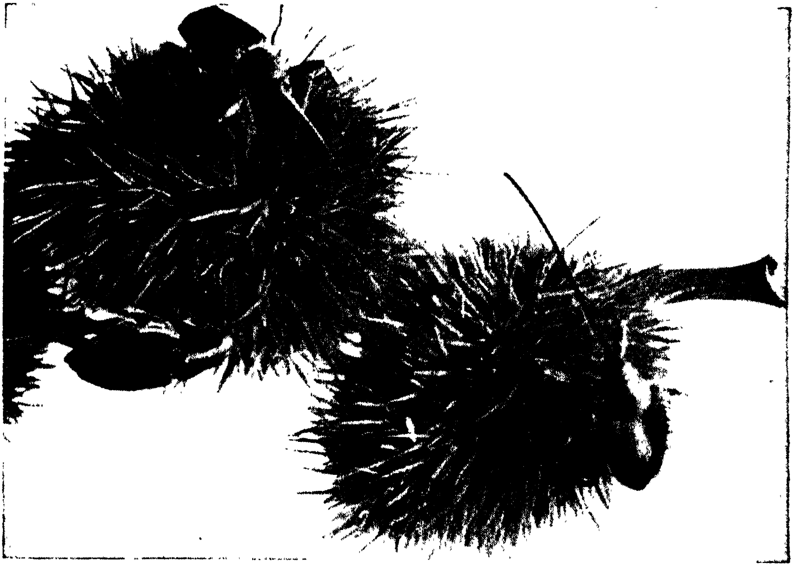
Isolation Other than Geographic Also Occurs.—Parasitic plants and animals are isolated on particular kinds of hosts. One caterpillar feeds on one plant, its nearest relative feeds on some different plant. The two insects are prevented from interbreeding as effectively as though they were a thousand miles apart. One scale insect will occur on apple; its nearest relatives, occurring in the same geographic area, are isolated on lilac and bush dogwood.

Similarly the season at which a plant opens its flowers, or at which the insect or other animal mates, may isolate it from a closely related species that occurs in the same locality but which matures at some later season. There are still other ways in which new types of individuals may be isolated.

Adaptations

Often it happens that the new characters developed by a hybrid or mutant are actually detrimental to its existence. A mutant bee with too short a tongue might starve to death because it could not get nectar out of flowers. Another insect that was born with eyes much smaller than normal might be unable to find its food. A mutant of a flowering plant that developed flowers that never opened might stand little chance of forming seeds. We say that such mutants are not *adapted* for existence.

On the contrary, some of the new types show special structures that seem of particular use to them in their struggle for existence. Any structure or physiologic characteristic which is useful to an organism is called an *adaptation.* The wings of a bird are adaptations of use to the animal in its search for food and shelter. The jaws and teeth of many vertebrates, the legs, wings, and fins of other animals, the root hairs of plants, and the wings and plumes on the seeds of maples, milkweed, dandelions, and thistles are all structures which aid organisms in their movements.

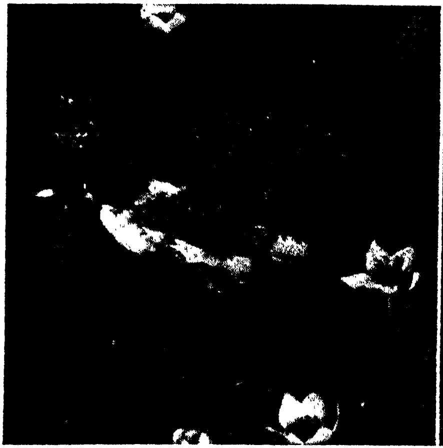


Courtesy U. S. Bur. Entomology

FIG. 269.—WEEVILS ON CHESTNUT BURS

They push their eggs into the burs with their long beaks, which are thus adaptations.

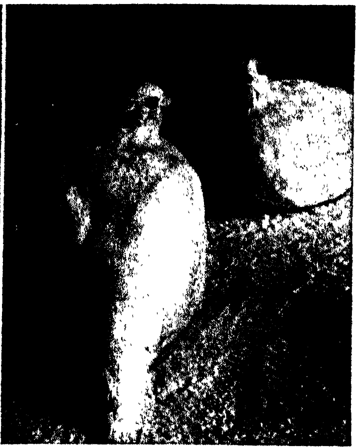
Other adaptations include skin, hair, wool, feathers, fingernails, and scales on vertebrates; the shell coverings of insects, molluscs, and turtles; teeth, fangs, muscular strength, and the ability to run; and plant structures like bark, thorns, stinging nettles, woolly coatings, and bitter and poisonous juices. Some animals are adaptively colored. Moths may look much like the bark on which they rest. The grasshopper covers its brilliant hind wings with its dull and mottled front ones. Some northern animals, like the weasel and the jack rabbit, are brown in the summer and white in the winter, an arrangement which protects them at all seasons.



Courtesy Amer. Mus. Nat. Hist.

FIG. 270.—SUMMER PLUMAGE

The ptarmigan, a far northern, American bird related to the ruffed grouse. The females of the birds are protectively colored.



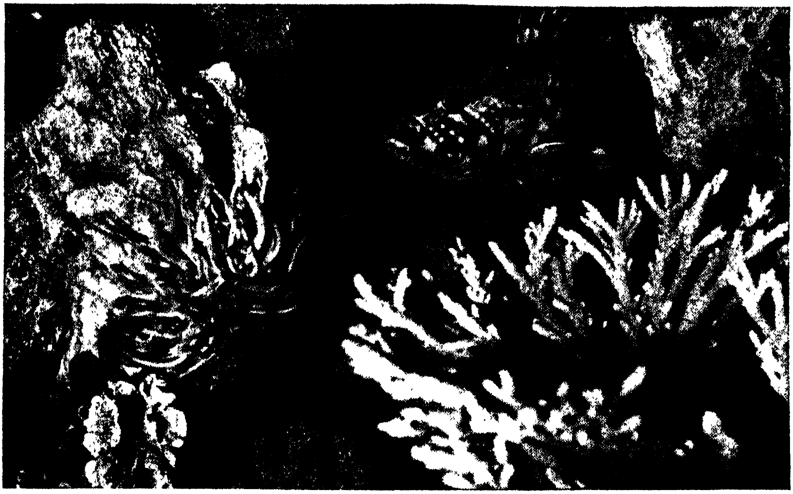
Courtesy Amer. Mus. Nat. Hist.

FIG. 271.—WINTER PLUMAGE

Of the same ptarmigan. An example of protective coloration changing with the seasons.

Some organisms mimic other things. Walking sticks closely resemble the stems of trees. Measuring worms, which are evident enough as they go galloping along, are difficult to see when their bodies are held stiffly out from the tree, for all the world like knotty twigs on it.

Pitcher-plant leaves are rolled up to form tubes in which rain-water readily accumulates. Insects enter, attracted by a sweet secretion within; but they cannot crawl out because of the stiff, downward-pointing hairs which carpet the entrance to the trap. After a struggle the exhausted insects fall into a watery grave. Plant secretions in the rain-water help digest the animals, which are then absorbed as food.



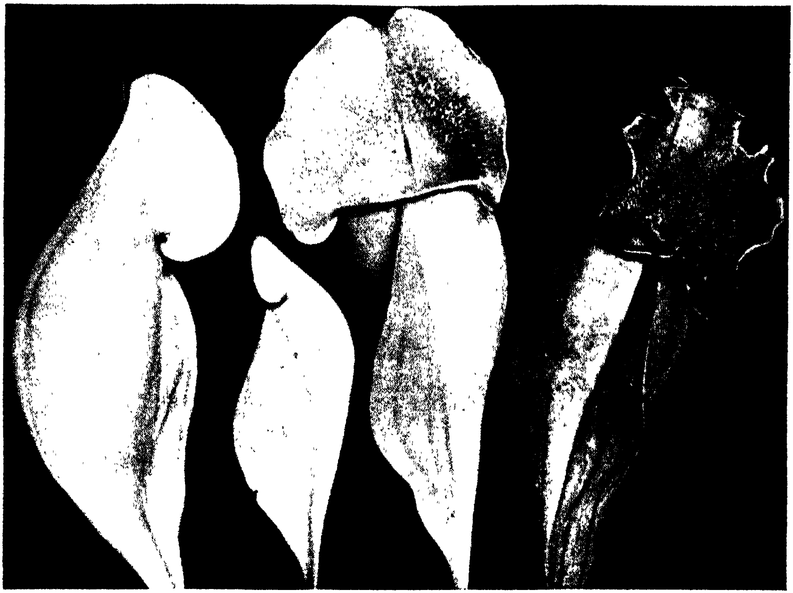
Courtesy Amer. Mus. Nat. Hist.

FIG. 272.—PROTECTIVE COLORATION IN A WEST INDIAN GROUPER FISH

It was Darwin, the English biologist, who suggested that the only new kinds of plants or animals that would survive and give rise to new species were those that had better adaptations than any of the previously existing individuals. That theory is known as the *survival of the fittest.* It is sometimes called *Darwinism.* This theory should not be confused with the theory of evolution as a whole. It is quite certain that all these things which we have named are really adaptations of considerable use to the plants or animals possessing them. There are, however, many biologists who feel that adaptations are of little importance in deciding whether a new type of mutant or hybrid will survive.

Evolution in the Past

The development of new species has occurred so often under our very eyes, both in the laboratory and in the field, that biologists believe that all living species must have come from previously existing species.



Courtesy A. A. Hansen and Nature Magazine

FIG. 273.—ADAPTATIONS IN PITCHER PLANT LEAVES
Note the inverted spines inside the lips.

But plants and animals have been on this earth for hundreds of millions of years. So the fossil records and the studies of the geologist show us. No man was present to record the changes that occurred in the past, but we have considerable circumstantial evidence about the past. It is possible for a detective to learn a good deal about what has happened, even if no living witness can be found. The evidence that evolution did actually occur in the past seems trustworthy, because there are several sorts of evidence, and all sorts tell the same story.

Similarities in Structure.—Clue number one is the fact that many organisms resemble one another in the way they are built. A cat is in structure something like a dog; it is less like a bird. We conclude that cats are more closely related to dogs, less closely to birds. Further studies show us that all of the mammals are more or less similar in structure. Bone for bone, muscle for muscle, nerve for nerve, a cat, a mouse, a giraffe, a whale are the same in plan of structure. The differences are for the most part differences in proportions and details of form. How may we explain the surprising similarities among all of these mammals unless we believe that they had a common ancestor from whom they evolved by repeated mutation, hybridization, and isolation, carried on over long periods of time?

Similarities in Physiology.—Clue number two is the fact that organisms are often similar in their physiologic constitutions. Delicate tests show that the blood of mammals of a single order (rodents, for instance), is all much alike, and unlike the blood of the species in some other order (cattle, for instance). All of the plants of the heath family, including the mountain laurels, rhododendrons, azaleas, heathers, arbutus, wintergreens, huckleberries, and blueberries, all of which are similar in structure, are also similar in physiology. For instance, every one of them grows best in soil which contains a great deal of acid and quantities of decayed plant material (*humus*). We seem justified in believing that all of the heaths had a common, remote ancestor.

Vestiges.—Clue number three is the fact that there are many structures found in plants and animals that are of no use, and may even be detrimental to the good health of the present-day species. *Vestiges* we call such structures. Some of the blind animals that live in the perpetual dark of caves have useless remnants of eye nerves that can never function. The nerves appear to be evidences of ancestors which possessed normal, functioning eyes. At the back of a horse's foot are two small "splint" bones which seem to be vestiges of toes; and fossil evidence confirms our belief that they are such structures. A fly has only one pair of wings, but behind them are two tiny vestiges, proof positive that the insects had four-winged ancestors. The eyes of a potato are vestigial buds, and in them will be found small, undeveloped leaves. At the base of each leaf on a corn-stalk is an ear of corn; all of the ears are vestigial except the normally developed upper ones.

Thousands of such instances could be given.

Vestiges are similar to the g's in such English words as reign and sign. The letter is not pronounced in those words, and is now useless, but it remains as evidence of their origin from the older Latin words *regnum* and *signum*.

Recapitulation.—The fourth clue is the fact that each organism in its embryonic development goes through stages representing the more mature forms of primitive animals or plants. We have already noted this in our study of embryology. The succession of embryonic stages is similar to our taxonomic arrangement of the main groups of organisms. We conclude that the lower forms represented in the younger embryos were the ancestors of the present animals and plants. It is thus that we explain such peculiar things as the gill pouches in the mammal embryo, for instance.

Fossils.—The fifth clue, and the best source of information as to the plants and animals which existed in the past, is the great mass of fossils which are actual preservations of the ancient organisms. Our next chapter will treat of these fossil records of the past.

From these and other clues biologists have gained information concerning the ancestral relationships of species.

SUMMARY

1. In the preceding chapter we have seen how new kinds of individuals come into existence. Can such new types of individuals give rise to new species? Individual variations due to the effect of environment on the body cells cannot be inherited; but characters arising through mutation or hybridization can be inherited. Do mutants and hybrids actually give rise to new species?

2. Species are tremendous populations of individuals with more or less common heredity. A species may consist of inconceivable millions of individuals, often spread over thousands or even hundreds of thousands of square miles. Throughout this vast population, over the whole of the great area, the individuals are much alike because they have been interbreeding, exchanging their genes, over long periods of time. As a result, all of them now have much the same kinds of genes.

3. Mutant or hybrid individuals are not new species, for they are not the large populations which are really species. Mutant and hybrid individuals may, however, give rise to new species.

4. If mutants or hybrids are located in the midst of the parental population they will interbreed with other individuals of the same species. The whole population is finally changed by having the new character added to the characters which the species had in the beginning. In this way an old species becomes more variable, but it is largely the same old species.

5. If, on the other hand, the mutant or hybrid is isolated from the parental population, it interbreeds only with individuals like itself, and finally it gives rise to a large population of individuals of the new type. Thus a new species is formed.

6. This isolation of mutants or hybrids is practised by plant and animal breeders who wish to secure new types for the garden, field, or farm. The method is called artificial selection, because it is man rather than some other factor in nature which is providing the isolation.

7. The taxonomists' studies have shown that every species in nature is isolated from its closest relative. This is one of the most important facts we have learned about species. Without such isolation, no species could have developed. The mutants or hybrids which give rise to new species are isolated by geographic factors, by differences in their hosts, by differences in blooming season or time of mating, or by other factors.

8. New species develop, then, from mutants or from hybrids which have been isolated from their parental populations.

9. Many organisms have characters which are of especial use to them in their struggle for existence. Such a structure or physiologic characteristic which is useful to an organism is called an adaptation. Darwin suggested that the individuals which possessed the best adaptations were the ones that would survive and give rise to new species. This theory is called Darwinism, or the Survival of the Fittest. Many biologists question how important adaptations are in deciding whether a new type of mutant or hybrid will survive.

10. There is considerable evidence that new species evolved in past ages much as we see them evolving today. The evidences are: (1) remarkable similarities in structure between many species; (2) similarities in physiologic characters; (3) vestigial structures; (4) the recapitulation which is shown in plant and animal embryos; (5) fossils.

DEFINE

Population
Isolation
Artificial selection
Adaptation
Mimicry
Darwinism
Survival of the Fittest
Vestigial structure

PROBLEMS

1. Make a list of all the things you can think of as possible factors isolating species in nature.

2. Show how isolation has had something to do with the development of the several human species (commonly called *races*).

3. Has hybridization ever given rise to new races of men? Give details.

4. Have two races of men ever become one when the isolating factors were removed? Give details.

5. For over a century immigration into the United States was practically unlimited. Now it is closely restricted. What effects would each policy have on the development of the American "species"?

6. How many of the structures of a horse (or a dog, or other familiar animal) seem to be adaptations? Make a list.

7. How many of the structures of that same animal appear to be useless, and not adaptations? Make a list.

8. How many of the structures of an oak (or other familiar tree) appear to be adaptations? Make a list.

9. How many of the structures of the same tree appear to be useless and not adaptations? Make a list.

10. We consider some classifications of plants and some classifications of animals as "artificial"; others are considered "natural." What is the difference?

11. Horse-radish, mustard, cabbage, cauliflower, pepper-grass, water-cress, and turnips are all placed in one family by botanists. What do you know about these plants that would show that they are all related?

12. Plums, cherries, peaches, and apricots belong to one genus. What shows the relationship of these plants?

13. Arrange the following mammals in three groups, indicating that they had three distinct ancestors: dog, antelope, pig, horse, musk ox, tiger, goat, cat, deer, wolf, bison, sheep, cow, fox, lion, reindeer, moose, wildcat, mountain goat. (Consider their teeth, hair, horns, feet, etc.)

14. We have circumstantial evidence that evolution occurred in past ages. What other sort of evidence could you expect to have?

15. Study and make a report on the evolution of something other than plant and animal species: on styles in human clothing, methods of warfare, the airplane, methods of transportation, the motion picture, the English language, or some other similar thing.

16. In growing potatoes to produce new varieties by selection, should the plants be grown (as the farmer grows them) from "eyes," or should they be grown from true seeds? Why?

17. New characters do sometimes develop in plants and animals that reproduce asexually—as in the cuttings of flowering plants, or in plant lice and wasps when the eggs grow without fertilization. In such a case, could new characters develop? Explain.

18. When members of the white race have their skins darkened by exposure to bright sunlight, they may become as dark as members of the brown races which are common in the tropics. How would Lamarck have explained the origin of the dark skins of such races? How would Darwin? How would modern biologists?

19. If you found two individuals that were very different (for instance, as different as the insects in Figure 261), how could you tell whether they belonged to the same or to two different species?

20. What is the difference between a variety and a species?

21. How many human species are there? Carefully consider the definition of a species.

22. In the eastern half of the United States, there are often broad transition zones between species. In these transition zones there are individuals that show every possible combination of characters of the two species. What process will account for these intermediate populations of transition zones?

23. Between most species in the western half of the United States, there are no transition zones with intermediate populations. Why is there this difference between the eastern and western halves of the continent?

24. Why have students of evolution paid so much attention to island faunas and floras?

25. Which parts of the North American Continent are fully as important as islands in the study of evolution?

CHAPTER XXVIII

FOSSILS

What could be more exciting than to meet, face to face, with one of the plants or animals that lived millions of years ago?

But look at this piece of amber. It is so clear that we can see a tiny wasp in it. Under a microscope the insect appears as perfect as though it had died but yesterday, although it is believed to have lived some millions of years ago on the shores of the Baltic Sea in Europe.

I wonder what sort of sea was there in those days, what plants grew there, what hot or cold weather, what storms or sunshine the insects lived through. Here are the jaws that chewed the stem of some plant that is now, probably, extinct. Here are the wings that balanced the creature as it climbed among the weeds. Here are the structures that, mayhap, laid living eggs in that long-distant day. One of the antennæ is broken, and one of the legs has parted at a joint. I wonder how those misfortunes befell the creature; what enemies, birds, reptiles, or beasts, tried to swallow the tiny wasp?

All I can be sure of is that one day it became tangled in the gum on the bark of some pine-like tree. Probably it struggled to get away. Was that how the leg was broken? And then the sap kept flowing, and the struggles of the wasp helped to bury it deeper, until finally it was completely covered, and it died. Now no animal could eat it. Not even bacteria could get at it to cause decay. When the old tree died the sap had become hardened, and falling into the ground it became in time a fossil of the clear sort which we call amber. In it the insect was preserved.

For long years the old sea arose and covered the land, and piled layers of material on top of the fossil. Then later the land again came out of the sea until one day, one really recent day, some man, I know not who, dug and found the amber, and passed it on, until finally it came to me. Geologists tell me that my insect died at least twenty-five million years ago. I cannot conceive what such a long time means. What a venerable thing my wasp is! What information it can give me as to how things were in the past!

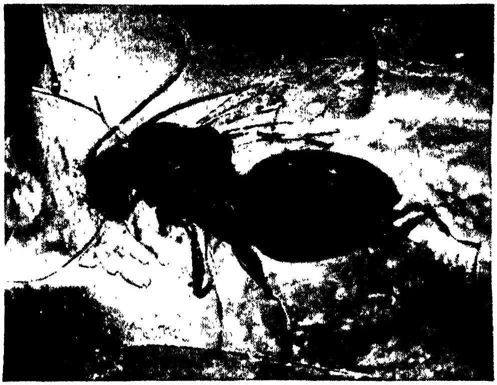


Photo by A. R. Addington

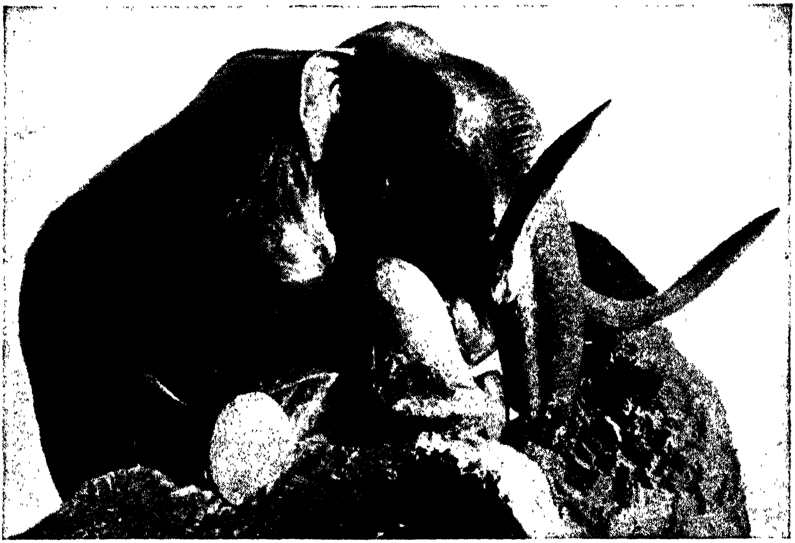
FIG. 274.—AN AMBER GALL WASP
Twenty-five million years old, more or less.

How Fossils Are Formed

Of course, not all fossils are as perfect as this one. But many of the amber specimens, thousands of which are known, are as perfect as this wasp. They are fossils of the sort that we call *whole preservations,* since they are the whole and actual organisms preserved from decay.

Whole Preservations.—Other remarkable whole preservations have been kept in ice or frozen tundra. In Siberia, and less perfectly in Alaska, ancient, elephant-like mammoths have been kept frozen for tens of thousands of years. When thawed out they are as pliable as a recently killed animal, and the flesh is eagerly devoured by the dogs of the Siberian people. Peat bogs and pitch pools similarly preserve whole plants and animals. One bed of pitch near Los Angeles, in Southern California, shows fossils of many ages, from the more ancient forms at the bottoms of the pools to the recent things higher up. Even modern species occur near the top, and it is still possible to see an occasional lizard or a rabbit enter a pitch pool and become hopelessly imprisoned. Gradually the unfortunate animal is drawn beneath the surface where it may be preserved for ages.

Petrifactions.—Most fossils are not the actual organisms, but petrifactions instead. In these the tissues were long ago dissolved away, bit by bit, by chemicals in the waters. Then dissolved mineral matter filtered into the empty places and hardened and became so like the originals in form as to appear little different from the living structures. Often the very cells of the original organism are imitated in their tissue and organ structures. Whole parts of trees are preserved in the petrified forests of Northern Arizona, California, Wyoming, and other parts of our West.

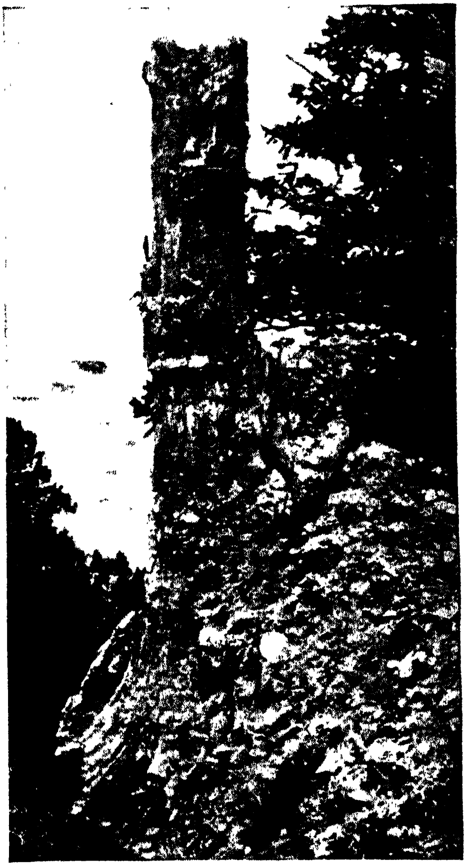


Courtesy R. S. Lull and Smithsonian Inst.

FIG. 275.—MAMMOTH FROZEN THOUSANDS OF YEARS AGO IN SIBERIA

Skin mounted in the position in which found. A fractured hip and foreleg, unswallowed grass between the teeth and on the tongue, and clotted blood in the chest indicated how suddenly the animal met its death.

Casts, Molds, Imprints.—Still other fossils are fossil casts, molds, or imprints, and they show only the general outer forms of organisms. Casts and molds may represent whole plants or animals, but often they represent only parts, a single wing, a leg, or some other such portion of the original plant or animal. Nevertheless, the specialists can get a great deal of information even out of the fragments.



Courtesy National Park Service

FIG. 276.—PETRIFIED PINE, YELLOWSTONE PARK

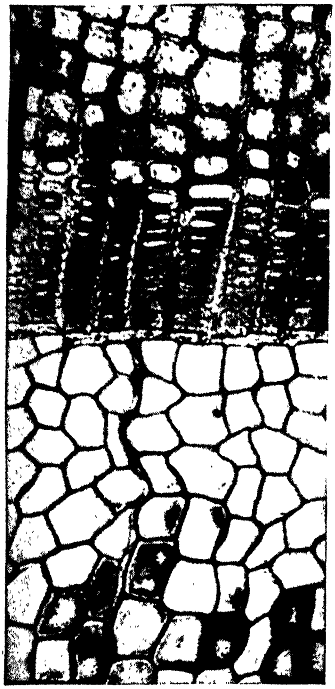
Even the bark is preserved, although these trees grew perhaps 20 million years ago.

It is much as with the hunter who sees only the track of the animal. He can, nevertheless, tell what kind of creature it was—that it was a small rather than a large individual, that it was lame in the one foot, that it had travelled rather slowly in a certain direction, that it was then chased by a dog, but that it escaped only to be captured finally by a great snowy owl that swooped upon it from the yonder tree. He did not see any of those things happen, but he finds a perfectly good record of them in the tracks in the snow.

It is so with the geologist who works with fragmentary fossils. They help him build the complete story of the past.

Near the tiny town of Florissant, Colorado, in the mountains that lie just west of Pike's Peak, great volcanic eruptions occurred some twenty million years ago. They filled the air with fine, volcanic dust, and insects, leaves, and flowers from the region were carried into a great lake and buried there. In this way one of the largest beds of American fossils was formed.

Naturally the harder parts of an organism are the structures most often preserved. Tree trunks rather than seaweeds, the skeletons of corals, the bones of vertebrates, and the shells of arthropods and molluscs are among the commoner fossils.



Courtesy National Park Service

FIG. 277.—CELL STRUCTURE OF PETRIFIED WOOD

Showing how exact the fossil record may be. Taken across a ring of annual growth.

Ancient Organisms

The plants and animals of the past were very different from those that live today. We know this from the fossils that have been preserved.

The fossils and the rock formations are our best records of conditions in the past.

Coal Age.[1]—There was, for instance, the Coal Age of about three hundred million years ago. It was then that most of the great coal beds of America were formed from plants that grew and accumulated in the swampy places of that day. There was a uniformly warm climate even as far north as Hudson Bay. In the dense forests there were plants that resembled our mosses, fern allies, and ferns, but many of them were as tall as the trees of our own times. The landscape was a sombre green, with no touch of bright color in it, for neither flowers, the higher insects, nor birds yet existed. The hum of bees and the fragrance of nectar were still things of the future. Lower insects, like cockroaches, were abundant, and many of them were very large. One fossil insect of that time measured twenty-nine inches between the tips of its wings. There were no locusts, nor crickets, nor birds, nor mammals to make the sounds now so familiar in our woods and our fields. Fish were abundant, amphibia were common, and the first of the land vertebrates, the reptiles, were just appearing.

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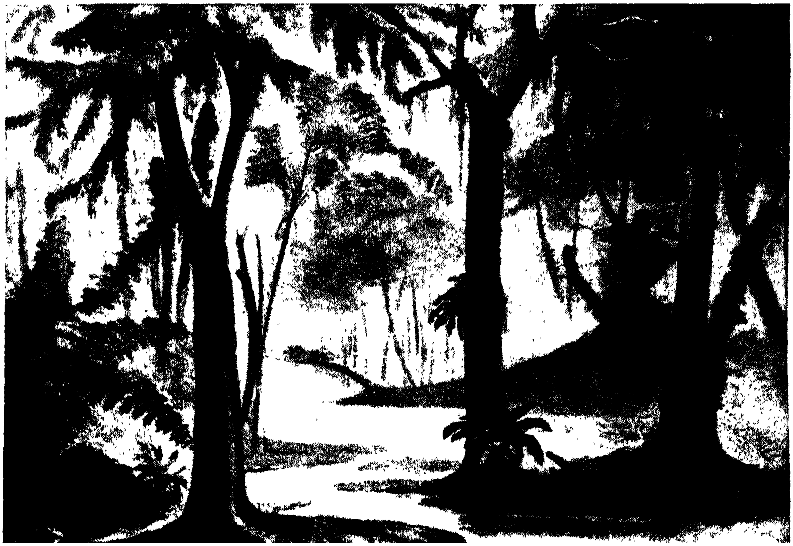
[1] Geologists call it the *Pennsylvanian* or *Upper* (more recent) *Carboniferous Period.*

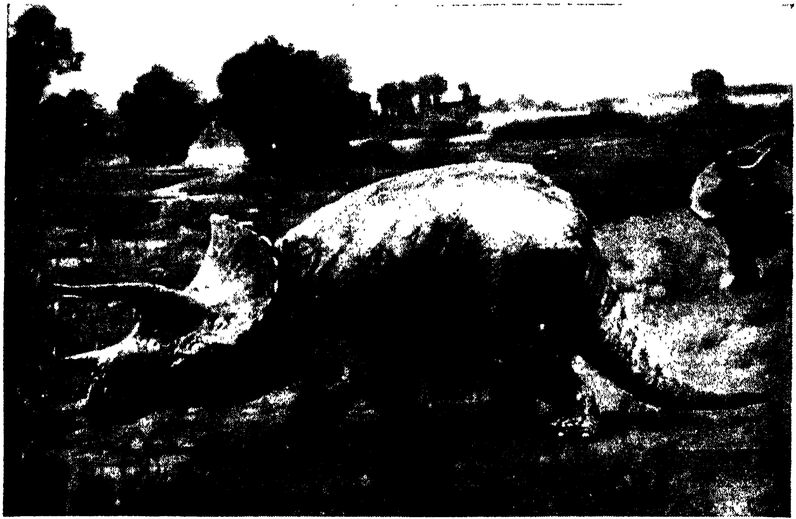


Courtesy U. S. Geological Surv.

FIG. 278.—A SWAMP OF THE COAL AGE

Tree ferns, fern allies, and seed ferns.

Age of Reptiles[1].—At a later time, but still perhaps a hundred and fifty million years ago, came the Age of Reptiles, when those scaly vertebrates flourished and developed some of the most extraordinary creatures that have ever existed. They lived in forests and in swamps where the plants resembled those of the Coal Age, although cone-bearing evergreen trees and some other seed plants also occurred there.



Courtesy U. S. Geol. Surv.

FIG. 279.—ANCIENT INHABITANTS OF MONTANA AND NORTH DAKOTA
Some of these dinosaurs had horns three and four feet long.

Some of the great reptiles walked, some crawled, some swam in the swamps and the oceans, others sailed through the air as dragons. There were huge beasts of prey with eagle-like claws, and they ran on their hind legs like monster ostriches. Other two-legged dinosaurs sprawled in wet places, using their duck-billed muzzles to feed on the vegetation of the swamp bottoms. Hugest of all were the vegetarian species, with long, snake-like necks, absurdly small heads, long tails, and great, spindle legs. Some of these creatures measured sixty to eighty feet in length, and they weighed forty tons, but their great bodies were only poorly controlled by brains that weighed less than a pound. Another giant reptile that once roamed our land was heavily armored with plates more than two feet high and four inches thick. One form had a huge head with a six- to eight-foot frill of bony plates about its neck, and a three- or four-foot horn on its nose. The fossils even show the deep wounds which some of the beasts received in what must have been terrific combats. We have also found their eggs, that were laid in the warm sands to be hatched by the sun, much as crocodile eggs are hatched today.

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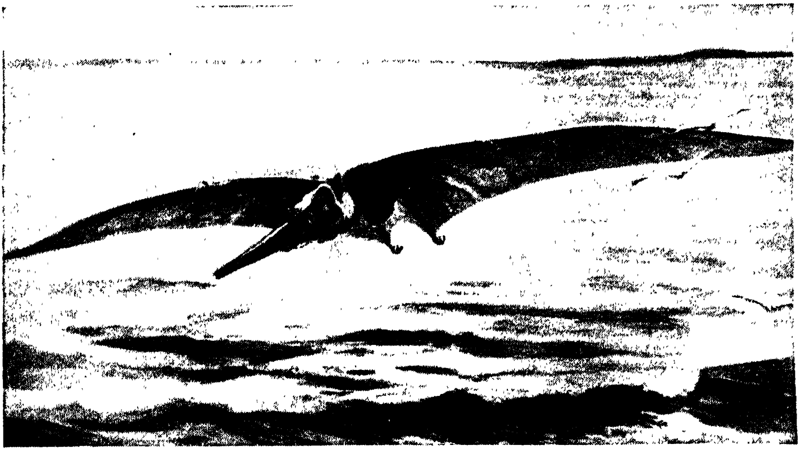
[1] Called by geologists the *Mesozoic Era.*

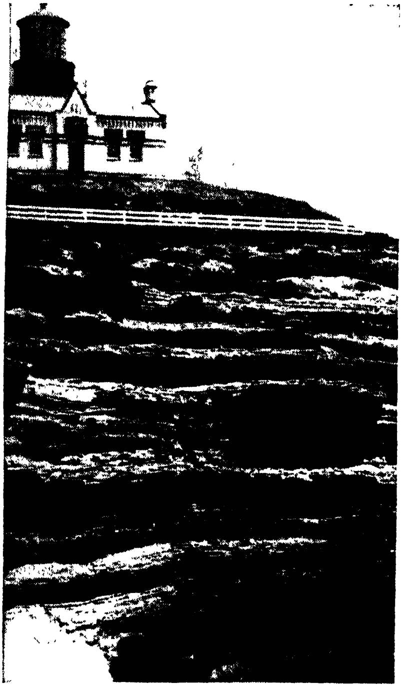


Courtesy U. S. Geol. Surv.

FIG. 280.—A FLYING DRAGON

At the close of the Age of Reptiles, these giant creatures suddenly, as geologic time goes, became extinct, and since that day the world has not again seen such remarkable animals. Before they went, the ancient reptiles had given rise to the flying dragons, which were strange combinations of reptile heads and tails with bird-like wings and mammal-like bodies. Some of these were several feet long, but others were as small as sparrows. The dragons in turn disappeared; but other reptiles had meanwhile given rise to toothed birds, with truly bird-like wings and feathers, but with other reptilian characters. These were the ancestors of our modern birds.

Age of Mammals.[1]—The most ancient mammals appear to have come from amphibian-reptile-like creatures. It was not until much later that the mammals became abundant, and at first most of them were small: tiny ancestral horses not twelve inches high, fleet-footed rhinoceroses, tiny camels, squirrels, and monkeys. The Age of Mammals did not begin until about sixty million years ago. That is in many ways a very long time ago. Indeed, it is completely beyond human understanding. But the fact that our modern flowering plants, the highest insects (butterflies, ants, bees, wasps) and the higher vertebrates were about as well developed then as now indicates how short a time that really is as far as the history of the earth and evolution are concerned. Relatively recently the huge mammoths, hairy, elephant-like animals, flourished in both Europe and America. We are living now in the closing days of the Age of Mammals, with the elephants, bisons, and whales among the few survivors of the large animals.



Courtesy U. S. Geol. Surv.

FIG. 281.—LAYER UPON LAYER, THE OLDEST ROCK AT THE BOTTOM

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[1] Known to geologists as the *Cenozoic Era.*

The Order of Evolution

We may determine the age of a fossil from the age of the rock in which it is preserved; for the two were formed at the same time.

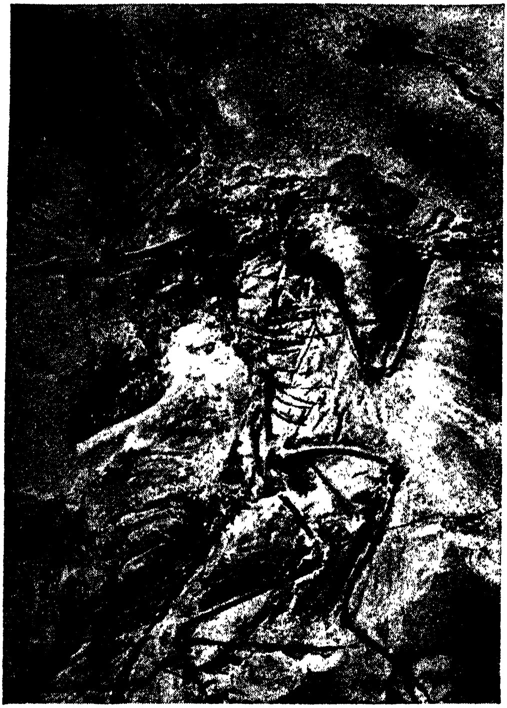
In some railroad cut or along a river bank you may see the exposed earth and rocks arranged in more or less horizontal layers, one on top the other. The oldest rocks are in general those that lie beneath. The layers were deposited on the bottoms of the seas or on the floors of valleys with the newer, younger ones always on top. Organisms that were entombed as the layers were put down became fossils in due time. Geologists can never tell exactly how many years ago any rock was formed, but they know that it took a long time in any case, and that the lower rocks are the older.

Now, the oldest fossils are very often simply constructed organisms. The more highly developed plants and animals appear only among the fossils of later times. The fossil series, arranged according to the ages of the formations, runs mostly parallel with the arrangement of plants and animals in our modern classifications. Here is evidence of the order of evolution.

Connecting Links.—Fossils even furnish the long-extinct connecting links between distantly related, present-day creatures whose kinships might otherwise be difficult to understand. The reptilian bird already mentioned clearly connects two classes of vertebrates. There are fossil insects that show the relation of the primitive, dragonfly-like insects with the ancient and on to the modern cockroaches. There are fossils of seed-bearing ferns that are intermediate between true ferns and flowering plants.

Moreover, there are remarkably complete series of preservations that show every intermediate stage between a primitive, long-extinct elephant that was no larger than a sheep and bore no trace of a trunk, and the long-tusked and long-trunked giants of yesterday and today. A similarly complete series connects ancient camels the size of a cat with the large camels that are now in existence.

To describe in detail only one of the several complete series of fossil connecting links which are known: The modern horse is peculiar in having a hoof which represents only one of the normally five toes of other mammals. It has a set of very complicated teeth, and a bushy mane and tail. Many different kinds of fossil horses have been found. The most ancient of these was as small as a fox terrier, twelve inches high, and it had four toes with remnants of a fifth toe on each of its front feet, simple teeth, no mane, and no bushy tail. Its relation to the modern horse would hardly be evident but for the many fossil connecting links between the two. The other fossils show that the four toes gave way to three, that the middle toe still later developed into a hoof, that the other two toes became degenerate splint bones, that the size of the whole animal gradually increased, that the teeth became more and more complicated, and that the other necessary changes in time produced the modern horse. Were all these



Courtesy Amer. Mus. Nat. Hist.

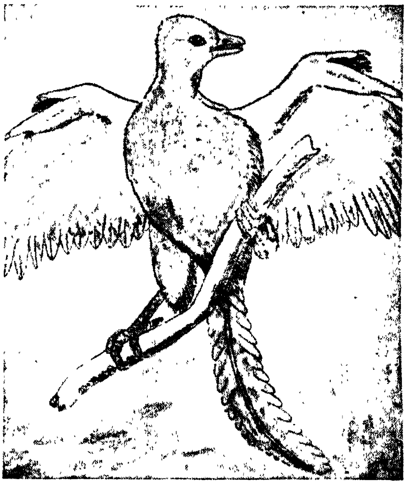
FIG. 282.—FOSSIL OF AN ANCIENT "CONNECTING LINK"

A reptile-bird.

changes to occur before our eyes today we could secure no more certain records than the fossils furnish us of this sixty-million-year history.

Fossil Hunting

Fossils are, with few exceptions, found only in sedimentary rocks. These rocks were formed from finely divided sediments deposited in successive layers beneath waters where they could entomb the ancient organisms and preserve them from too rapid decay. Sandstones, shales, and limestones, particularly the latter, are the sedimentary rocks which most often contain fossils. The igneous rocks, formed by the action of intense heat, destroyed all the organic remains about them, and fossils almost never occur in them.

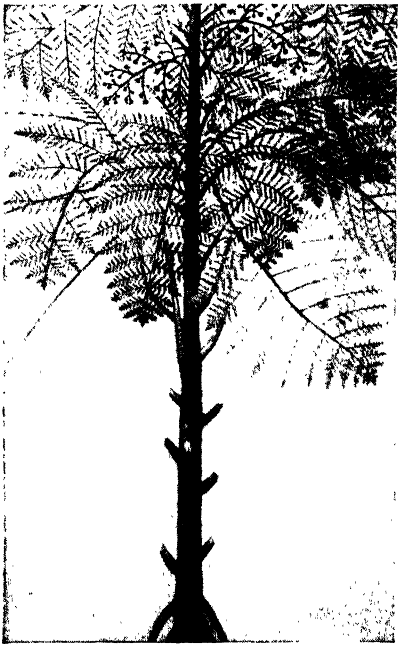


Courtesy Amer. Mus. Nat. Hist.

FIG. 283.—RESTORATION OF THE REPTILE-BIRD

Many of the first finds of fossils are accidental. Along the banks of a river, in a railroad cut, where there have been landslides, excavations for buildings, or quarry operations, the sedimentary rocks may disclose treasures. The first find is the clue for the location of others. Dr. Walcott, of the U. S. National Museum, found a few fragments of fossils at the base of a mountain near Field, British Columbia. Reasoning that these must have come from higher on the slopes, he climbed and dug until he located a very rich deposit of about the oldest fossils known.

Most of the known fossils have come from a certain few localities, but chance specimens may be picked up near most of our homes. A few years ago the digging of a foundation for a new hotel in Washington, D. C., disclosed for the first time that that city is built over a bed of fossilized swamp plants. In many parts of our country the common rocks are limestones, and some of these consist of little else than fossils of lower animals. The running waters of such regions often cut out fine specimens of fossils that may be picked up along the streams and lake shores. There are large sections of the United States where fossils are so common that they may be picked up in one's dooryard, or along any stone ledge or brookside in the neighborhood.



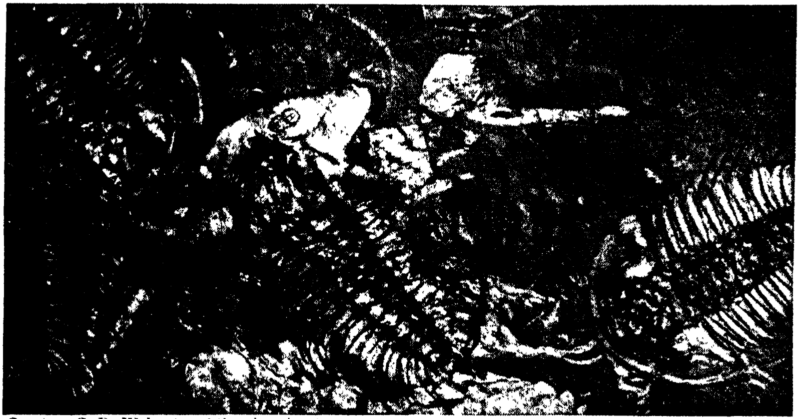
Courtesy E. W. Berry and Smithsonian Inst.

FIG. 284.—RESTORATION OF A SEED FERN

A fossil connecting link between ferns and seed plants. Note the clusters of seed-like structures.

The fossils of vertebrate bones are more often deeply embedded in the rocks, and usually they are secured only after deliberate exploration.

In the old days, in the recently old days of a half century ago, the professor who had learned of a vertebrate fossil that had accidentally been found in a certain region searched out a half dozen of his students who were ready for some excitement during a summer vacation, and travelled off to the suspected locality. Perhaps they had to go as far as the railroad could take them, and then, outfitted with horses and wagons, food and cooking utensils, blankets and tents, and taking an Indian for a guide, they set off over the trackless plains beyond civilization. If they were in bad Indian country, the Government provided soldiers for protection. The soldiers were much disgusted with the men who tapped rocks to see what was in them. After some days a great river bluff was espied in the distance, and when they got to it they carefully dug and split out slabs of stone that showed the fossils of hundreds of bones.



Courtesy C. D. Walcott and Smithsonian Inst.

FIG. 285.—FOSSIL ARTHROPODS FROM BRITISH COLUMBIA
As old as any known fossils, possibly 600 million years old.

Then everyone in the party became interested, and worked hard with picks and spades. Three or four weeks of such rough living and hard labor filled their wagons with stones, and the party returned to civilization.

Modern fossil hunters often work in much the same way, going off by auto or more primitive caravan into some unexplored part of the world, or employing trenching and modern quarrying machinery to cut into the suspected rocks nearer home.

Preparing Fossils for Study.—It is often difficult to get a fossil out of the hard rock of which it is a part. Usually only a bit of the plant or animal is exposed on the surface. Gentle taps of the hammer may loosen some specimens. More often the fossil must be carefully bound in place in large pieces of

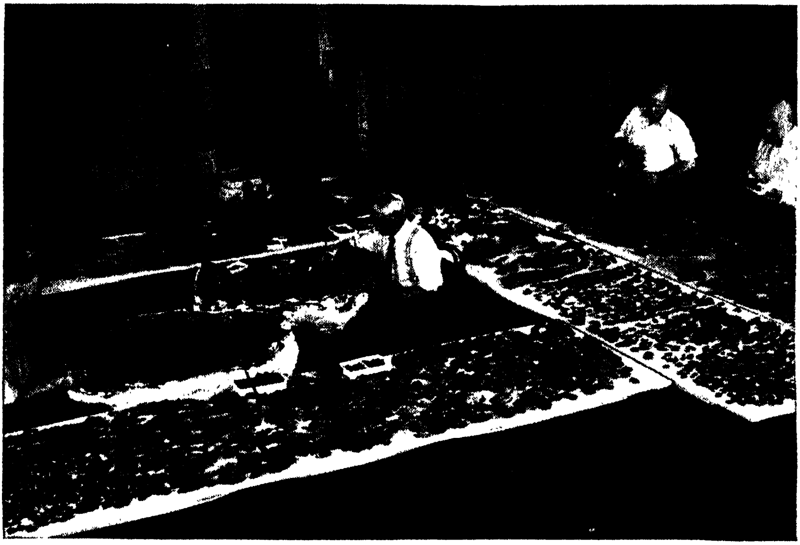
Courtesy Amer. Mus. Nat. Hist.

FIG. 286.—UNCOVERING FOSSIL BONES

Courtesy Amer. Mus. Nat. Hist.

FIG. 287.—HAULING FOSSIL SPECIMENS TO THE RAILROAD

rock which are shipped by the carload to some museum or university laboratory. There the skill and care of a surgeon is employed by the scientist who chips away bits of the rock until only the fossil remains. Sometimes many years of such work are necessary to recover a single specimen.



Courtesy Amer. Mus. Nat. Hist.

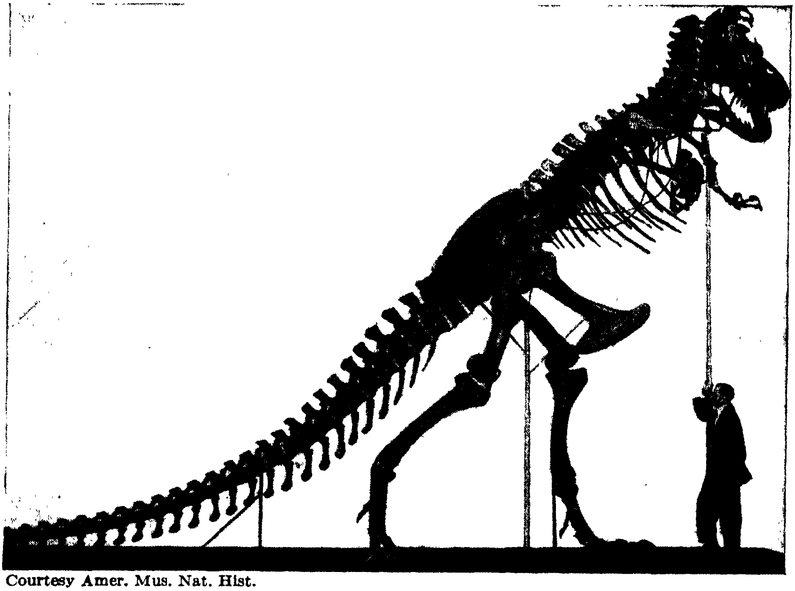
FIG. 288.—PUTTING JIG-SAW PUZZLES TOGETHER

From these many pieces, experts make reconstructions such as are pictured on the next pages.

When the creature comes out it is usually in small pieces. Many of the parts are completely lost. The puzzle can be put together only by the expert who knows how such things are constructed, and whose imagination can direct the modelling of pieces to replace the lost parts. Finally there may emerge such a form as no man has before seen, and you and I may go to the museum and examine the reconstruction, or easily look at its figure in some book. Then it is well if we remember the fossil hunters whose labors have unfolded the tale of the past.

SUMMARY

1. Fossils provide us with a means of becoming acquainted with the plants and animals that existed on this earth in past geologic ages, millions and even hundreds of millions of years ago.



Courtesy Amer. Mus. Nat. Hist.

FIG. 289.—RESTORED SKELETON OF AN ANCIENT REPTILE

2. Some fossils are preservations of the actual plant or animal tissues which have been preserved from decay, for long periods of time, by being imbedded in amber (the hardened sap of conifers), in ice, in pitch, or in peat bogs where bacteria of decay are unable to reach them.

3. Petrifactions are fossils in which the plant or animal tissues have been replaced, cell by cell, with mineral materials. Casts, molds, and imprints are fossils in which the general form of the plant or animal is preserved in mineral materials, but the details of internal structure are lost.

4. These several types of fossils have preserved a clear-cut record of the faunas and floras of the past.

5. They show us that in the Coal Age mosses, ferns, and fern allies formed the forests; insects were abundant; but no flowering plants and no higher insects were to be found.

6. In the Age of Reptiles fern forests were still common, but conifers and some seed plants had appeared. The prominent vertebrates were giant reptiles, as large as any of the animals that have lived on this earth. At the close of this period, flying reptiles were evolving into modern birds.

7. Fossils occur chiefly in sedimentary rocks which were formed, layer on top of layer, under water. The oldest layer is at the bottom, the most recent layer on top. The age of a fossil may be determined by the position of the layer of sedimentary rock in which it occurs.

8. The highest taxonomic groups (*e.g.*, higher seed plants, flies, bees, wasps, birds, mammals, etc.), do not appear until late in the fossil record.

9. Starting with the older fossils, it has been possible in many cases to find complete series that show the steps in the evolution from ancient to recent types of plants and animals. For instance: The history of the horse is one on which we have remarkably complete fossil records; fossils of seed ferns are connecting links between ferns and seed plants; the reptile birds are connecting links between reptiles and birds.

10. Fossils are found abundantly in most sedimentary rocks, especially in limestone. In many parts of the country they are easy to find along streams, on exposed rock ledges, etc. Fossil hunters have been among the most industrious of biologic explorers. The specimens we may see in the museum represent much hard work in finding and digging the bones, and harder work in putting the many pieces properly together so we may obtain a true idea of the plants and animals that existed in the past.

DEFINE

Fossil
Amber
Whole preservation
Petrifaction
Mammoth
Fossil cast
Fossil mold
Fossil imprint
Sedimentary rock
Igneous rock
Coal Age
Age of Reptiles
Age of Mammals
Dinosaur
Fossil connecting link
Reconstruction (of a fossil)

PROBLEMS

1. Have you ever seen an actual fossil (in museums, or in sandstone, limestone, or other rocks)? Describe.

2. Now can you explain why we have no historic, man-made records of a plant or animal of one class, for instance, changing into one of another class?

3. Under what conditions could present-day organisms become fossils? Why do most of them fail to become fossils?

4. In which phyla of plants and in which phyla of animals would fossils be most likely to form? Explain.

5. Can you find a place near your home where the rock is stratified? If so, get a photograph of it, or draw a diagram of it to bring to class. As far as you can, explain how it was formed.

6. What can you find out concerning the known fossils of man?

7. Have you ever seen what might be the beginning of the formation of a bed of fossils? Describe.

8. Of all the evidences, which two do you think furnish the best proofs that species change? Why?

9. Make a list of the phyla and main classes of plants and animals: check those for which fossils have been mentioned in this text.

10. Why is our fossil record of plants and animals so incomplete? There are several reasons for this.

11. Try to find out how geologists are able to tell how many years old a fossil is.

12. Which figures in this book, outside of the present chapter, show fossils?

13. In the previous chapter you were asked to tell how two different individuals could be recognized as belonging to the same or different species. How could one tell whether two similar but different fossils belonged to the same or different species?

14. What is the difference in meaning between *petrified* and *fossilized?*

15. Why did the giant reptiles and the giant mammals become extinct?

16. Why does one of the oil companies use a dinosaur in its advertisements? Explain in detail.

17. Make a diagram, to scale, showing how long ago human history began (about 4000 B.C.), and how long ago the organisms of Figures 274, 275, 276, 278, 285, and 288 lived.

18. What practical, dollars-and-cents value is there in a study of fossils?

GENETICS: REVIEW

1. Review the definitions of all the words listed at the ends of Chapters XXIII through XXVIII.
2. Review all of the summaries at the ends of those same chapters.
3. Review the problems given at the ends of those chapters.
4. Explain what is meant by each of the following statements. These are the important principles in that part of Genetics which you have studied.

CHAPTER XXIII. **Heredity.**—An individual does not inherit its characters. It inherits genes which are located in the chromosomes of the fertilized eggs. These genes, however, control the way in which the individual develops.

Because certain characters are dominant, others recessive, the offspring in the F_2 and successive generations will be in part pure dominants, in part hybrids, and in part pure recessives.

Hybrid individuals carry recessive genes which do not show, and dominant genes that do show. If the recessive characters are undesirable, then matings of similar hybrids should be avoided.

CHAPTER XXIV. **Heredity and Environment.**—Neither heredity nor environment is more important in determining the characters of an individual. Heredity provides the equipment, the environment controls how much of that equipment may be used.

CHAPTER XXV. **Value of Scientific Research.**—Scientists believe that anything true is worth discovering. Much of their research is done without any idea of the practical applications that may result. The work of Mendel and the students of chromosomes illustrates how valuable such theoretical research may ultimately prove to be.

CHAPTER XXVI. **Individual Variation.**—No two individuals are exactly alike.

They may differ because of the effects of the environment on their body cells. Lamarck believed such characters could be inherited, but biologists do not find that characters acquired (through the effects of environment) during the lifetime of an individual can be inherited.

Individuals also differ because each is a hybrid of two parents, such a new combination as never existed before.

Individuals may differ because of actual changes, *mutations,* which have occurred in their genes.

CHAPTER XXVII. **New Kinds of Organisms.**—Species are large populations with more or less common heredity. New types of hybrids or mutants are new individuals, not new species. New hybrids or mutants give rise to new species only when they are isolated. Then they may develop populations which are pure for the new characters.

Such isolation (called artificial selection) is always provided by breeders who wish to develop new kinds of plants or animals. Taxonomists find that species in nature are always isolated from their nearest relatives.

Darwin believed that only those new types which had the best adaptations would give rise to new species. This now seems to be of doubtful importance in the origin of species.

There is abundant evidence that the evolution of new species occurred in the past much as it is observed to occur today.

CHAPTER XXVIII. **Fossils.**—Fossils provide us with a means of studying the plants and animals that existed in past geologic ages.

Fossils indicate that ancient organisms were very different from present-day species, and they provide "connecting links" which show how the modern species developed from the ancestral types.

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*Books recommended as the best volumes for the high school reference library.

UNIT VI

Relations of Plants and Animals to Their Environment

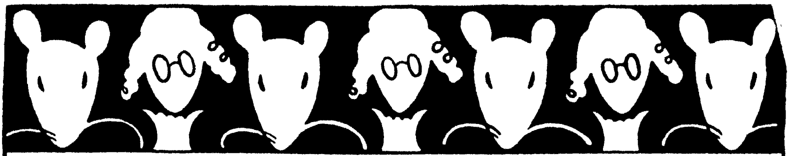
⁂

The Biologic Science Called

ECOLOGY

⁂

ECOLOGIC RELATIONS
EPIDEMICS
PEST CONTROL
FOREST ECOLOGY AND CONSERVATION
INSECTS
BIRDS
INSECTS AND FLOWERS
FRESH-WATER BIOLOGY
PROBLEMS IN CONSERVATION



Preview

The Greek word *ecos* means *household;* and *ology* is of course *a study of.* Ecology is, therefore, another word with a lot of meaning packed into it.

But the households that we are going to study are not inside of four walls built by human hands. They are—well, what kind of households *are* we going to study?

For instance, here is a clover plant. Is the bumblebee part of its household? Is the soil in which it is growing? And the sunshine and rain that fall on it? And—weeds? weevils? moonbeams? mice? earthworms? houseflies? and old maids? The clover does not live its life alone. It is constantly being affected by everything, living and non-living, that comes into contact with it.

Yes, you will even find a story about old maids and clover, if you will read through the pages of this unit.

And a story about pests that become epidemic. And accounts of the ecologic households that trees, insects, and birds live in. And, indeed, the part that we, ourselves, have in those households!

There is an endless list of ecologic relations we might study. Name some of them. Which of these will contribute to your knowledge of conservation?

CHAPTER XXIX

ECOLOGIC RELATIONS

Once, in northern Vermont, I killed an insect on a weed stem. I wonder what effect that had on the cost of living in New England. Who knows?

Did the weed flourish more because the insect was killed? Did it, therefore, scatter a thousand seeds that could not have developed if the insect had lived? In the next year did the weeds which grew from those seeds, uncontrolled by the insect and its possible descendants, ruin enough of the farmer's crops to help raise the price of things in the markets? Perhaps other farmers had similar misfortunes, and perhaps I added the last drop necessary to make the bucket of calamities overflow.

On the other hand, that particular weed might have died anyway, and perhaps the insect and its descendants would have done more harm to the crops than to the weeds. A bird might have eaten the insect if I hadn't killed it. Or a toad might have got it. Perhaps—any number of things, the outcome of which would be beyond reckoning.

But certainly, the insect, the weed, the birds, the toads, the farmer, the crops, and the cost of living in New England were all interrelated things, that were much affected by what happened to one another.

It requires no great stretch of the imagination to think of everything in the universe as being related to everything else. Every living creature serves as a food or an enemy, a source of prosperity or of misfortune, and a means of furthering the life or of hastening the premature death of every other living thing. No creature exists independently.

The above is an illustration of an ecologic relation between organisms. Ecology is the science which considers such relations of organisms to their environments.

FIG. 290.—A BIT OF WEST TEXAN ECOLOGY

The arid climate and alkali soil, the yucca, greasewood, sparse grasses, cacti, insects that live in them, desert birds, prairie dogs, etc., are all part of the ecologic story. All these environmental factors are part of the biology of the plant.

Why There Are Ecologic Relations

Living organisms are always involved in ecologic relations with other organisms or with their inorganic (which is their non-living) environment. This is because all creatures have three fundamental concerns in life. They must find food. They must escape enemies. They must reproduce.

The more direct the contacts between the organisms, the more important the relations that result. The Vermont insects usually affect the Vermont crops more seriously than the crops of some distant part of the country.

Sometimes indirect relations are important. Man, for instance, is concerned with the prosperity of the birds, not because he often comes into direct contact with them, but because they are among the enemies of the insect pests that eat human food crops.

The ability to move about increases an organism's ecologic importance. It is chiefly because plants do not move from place to place that they are not so strikingly important as the insects, the birds, and man. The great importance of birds is in part due to their powers of flight, which enable them to control weeds and insects over widespread areas. As man increases his powers of locomotion, by the use of railroads, autos, and airplanes, he is becoming increasingly capable of controlling, of using, or of otherwise affecting the other organisms of the world.

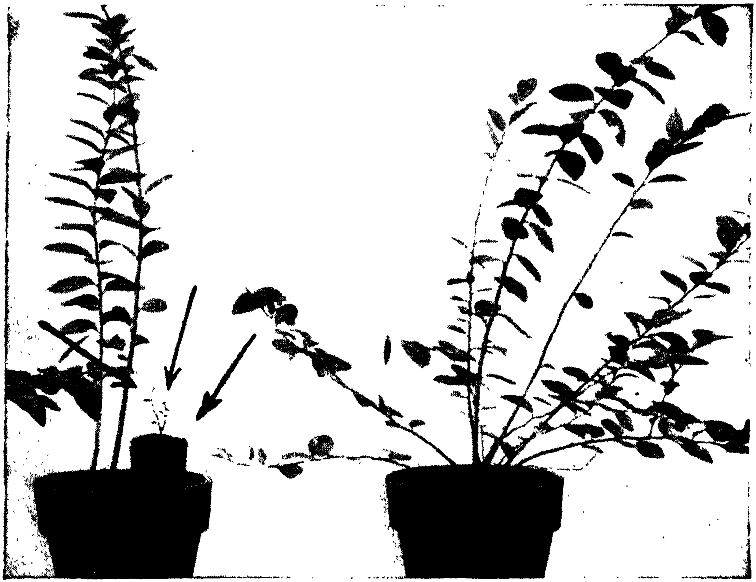
The size of an organism may have much to do with its importance. Trees are ecologically prominent because they take up so much room and cover and protect so many other organisms and wide areas of soil. Animals, on the other hand, cannot easily move about if they are too large, and the smaller animals, particularly the insects, are among the most successful things living today. Many small organisms, like the bacteria, gain their importance because they are so small that they can reproduce rapidly and because their enemies cannot readily locate and destroy them.

Types of Relations

Organisms are affected both by their dead, what we call their *inorganic* environments, and by their living, the *organic,* environments.

Inorganic Relations.—The growth and existence of a plant depends upon conditions in the non-living part of the world about it. It depends upon temperature, on the amount of water and food available, upon light conditions, upon the texture of the soil, the severity of the winds, the chemical content of the air, atmospheric pressure, and electric conditions. White pine trees grow well only in northern regions which have a considerable amount of freezing weather in the winter; the long-leaf pine, on the other hand, is confined to certain sunbaked parts of the South. The delicate flowers common in woodlands require much shade; but daisies and sunflowers and poppies grow best in the blaze of the sun. A small amount of sulphur gas from a copper smelter will kill most of the plants in the neighborhood. Mild treatment with electric currents will induce many plants to increased growth.

Animals are similarly dependent upon their inorganic environments. Mosquitoes are most abundant in wet regions, for they require water in which to live during their younger stages. Earthworms usually wait for dusk and the darkness of night before they wriggle above ground. Many kinds of lake salmon retreat to the deeper, colder waters in the summer, but any fisherman knows that shallower waters are the best places for pickerel. Crickets chirp only on warm evenings, and the warmer the night the faster they sing. Humans, many of them, become inefficient and irritable when the temperature is too high, especially if the atmosphere is heavily laden with moisture.

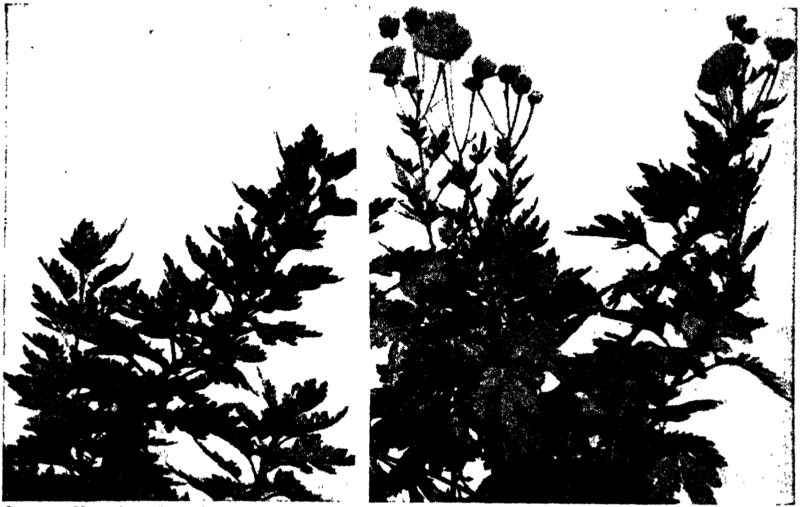


Courtesy U. S. Bur. Plant Industry

FIG. 291.—BLUEBERRY PLANTS REQUIRE ACID SOIL

The plant in the small pot was grown in non-acid soil.

Organic Relations.—These are ecologic relations between two or more organisms. They are called *sexual* relations when individuals of the same species but of opposite sexes are concerned. They are called *threptic* relations when parents and their offspring are involved. Among animals, where many individuals of both sexes, including both adults and young, live in a single community, the relation is said to be *social.*



Courtesy U. S. Bur. Plant Industry

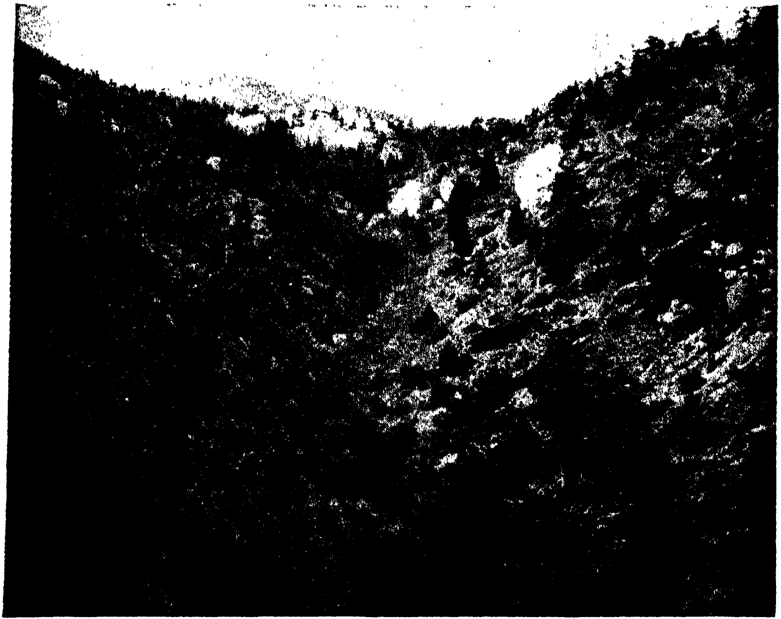
FIG. 292.—CHRYSANTHEMUMS BLOOM WHEN THE DAYS ARE SHORT

Both pictures taken in midsummer, but the plants on the right were protected from the light for part of each day.

Symbiosis is a wholly advantageous relation between organisms of different species. Thus, mosses profit by growing on tree trunks, and usually do no harm to the trees. Young clams are carried many miles attached to the gills of fish, much to the young mollusc's advantage, and without any special detriment to the animal that is the host. The flowers that attract bees benefit by having pollen carried from their stamens to their pistils, and the bees receive nectar and pollen food in return.

If one individual directly kills another, the relation is called *predatism*. Lions, pursuing and killing their prey, are predatory animals.

When one party feeds upon another, but kills it (if at all) only after a period of time, the relation is called *parasitism*. Fungus parasites living on trees or herbs may not kill their hosts until months or years after they first attack. Such parasites as lice and fleas may never kill their hosts, although the victim may be uncomfortable enough.



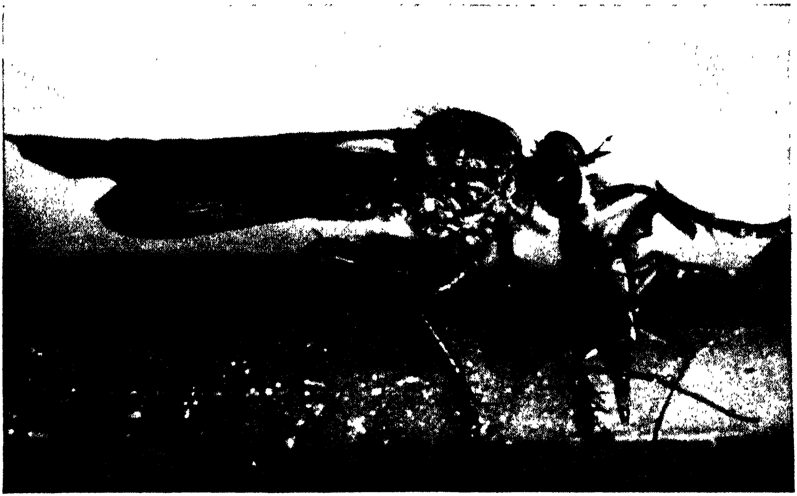
Courtesy F. E. Clements and Carnegie Institution

FIG. 293.—EFFECTS OF NORTH AND SOUTH EXPOSURES, IDAHO

The hillside exposed to the north bears the evergreen forest.

Scavengers feed on dead organic material. Buzzards, dung beetles, and maggots are animals that are scavengers. Plant scavengers that feed on the decaying materials in woods soil are often called *saprophytes*.

Economic Relations.—All of the above names suggest the differing ways in which organisms may be related. If any of these relations, of any type whatsoever, includes man, it is also said to be economic. The insects that injure or benefit man are the species studied in economic entomology. The coal, oil, and metals which may be dug from the ground and utilized by man are parts of our inorganic, economic environment. Our system of laws and social customs, and our schools and business concerns and churches, are all ecologic situations which are economic, for they are concerned with the fate of the human animal.



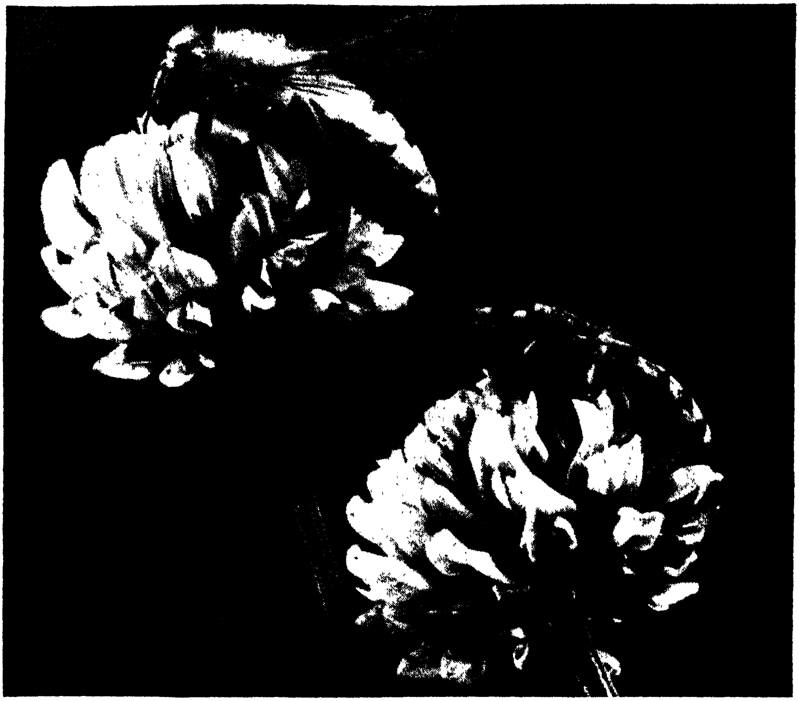
Courtesy P. G. Howes, from Insect Behavior, Badger Publ.

FIG. 294.—A PREDACEOUS FLY CAPTURING A GNAT

Chains and Webs of Relations

Of course, ecologic relations do not stop with pairs of organisms. Each pair is related to other pairs, and these in turn to others, until long chains of relationships may be found.

A biologist was asked to discover what effect sewage dumped into the Hudson River at Albany might have upon the city of New York, a hundred and fifty miles down the same river. He found that the sewage was first attacked by microscopic bacteria and protozoa; that farther along those organisms were consumed by other microscopic forms; that still later these second forms were eaten by tiny crustacea; that the crustacea were then eaten by fish; that farther down the stream the small fish were eaten by larger fish; and that the larger fish, caught at the mouth of the river, were then being sold as food in the markets of New York.



Courtesy A. I. Root Co., Medina, Ohio

FIG. 295.—HONEYBEES GATHERING NECTAR AND POLLEN FROM CLOVER

A classic instance of such a chain, first pointed out by Darwin, shows that the size of the red clover crop depends first of all upon the number of bumblebees in the region, for bumblebees are the most important insects in the distribution of the pollen of the plant; secondly upon the number of mice, since mice are among the worst enemies of bumblebee nests; and thirdly upon the number of hawks and owls and cats, the arch enemies of mice in any region. But Huxley, another great English biologist, pointed out that the number of cats, and, therefore the size of the clover crop, further depends upon the number of old maids in a community.

Such chains of relationships take into account only the most important, or at any rate the most conspicuous, organisms involved. A more complete picture of the situation would show a web of relationships with threads and crossings beyond number. That we most often talk about the simple situations in ecology is due to the fact that the web is beyond our understanding. Keep your wits keen, and discover as much as possible about the relations of the organisms which you commonly meet. You will find a tangle, a puzzle that will be interesting.

Conservation of Balanced Conditions

With every one of millions and endless millions of creatures fighting for its own food, its own life, and its own chance for reproduction, where does it all end? Who wins? Who is exterminated?

The answer is that few species ever win, few species are ever exterminated. Rather we find that balanced conditions may exist in nature. Each species prospers just so much, no more, no less; no more because its enemies prohibit it; no less because its enemies are similarly limited in their powers. As soon as predators or parasites become too prosperous their hosts become too few, and some of the very creatures that worked the destruction die of starvation. There persists just enough, no more, of each and every species under balanced conditions.

If two men pushed on opposite sides of a cart, it is possible that one of them would become the victor and that the cart would move in a single direction. But if a hundred men should all push the cart from every possible direction, it is probable that the cart would never get very far. It might move a bit to one side, a bit to the other, forward or backward, as a surge of the crowd affected it. But the chief result would be practically an equilibrium. Balanced conditions in nature represent such a state of affairs; only there, thousands of forces contend to bring about the balance.

Balanced conditions are good conditions for each and every one of the species involved. Somebody gets run over every time one organism prospers too much. The chaotic, disorganized state of an upset is not healthy, even for the disturber of the peace. It is a foolish man who seriously upsets a naturally balanced state of affairs.

But that is exactly what man has been doing, especially during the recent centuries of his history. With his more than animal abilities because of the tools he can devise, his fire, his saw, his axe, his plough, his mills and his engines, railroads and autos, guns and dynamite, man has very often deliberately exterminated other animals and plants. No other organism has done so much to upset the balance of things.

In the long run the upset has not been profitable for anyone, not even for man. One generation has cut and burned and destroyed the forests, but the next has had to pay in floods and ruined soil. Once men shot birds in great numbers, but there followed epidemics of weed and insect pests that interfered with the growing of our crops. We have allowed stray insects to ride on steamships, in freight cars, and on imported stuffs, and today we suffer from foreign pests that were unknown to our forefathers.

Epidemics Are the Inevitable Results of Upset Balance.—The problems of pest control are chiefly problems of restoring and maintaining balanced conditions. They are the biologic problems with which we as a nation shall have to be most concerned. If our beginning study equips us for our responsibilities as citizens, biology will again prove itself a practical science.

SUMMARY

1. Every living creature is dependent upon its environment for its existence. No creature exists independently. Ecology is the biologic science in which such relations of organisms to their environment are studied.

2. Organisms are always involved in ecologic relations, because they must feed, escape enemies, or reproduce.

3. Usually the more direct the contacts between organisms, the more important the relations. Some indirect relations are important. The ability to move about increases an organism's ecologic importance. Large size may increase ecologic importance, but very small size more often results in great importance.

4. Inorganic relations are those that exist between an organism and its non-living environment (foods, water, sunlight, temperature, etc.).

5. Organic relations are called sexual (when between individuals of the same species but of opposite sex); threptic (between parents and offspring); social (between adults of both sexes and all ages); symbiotic (when entirely advantageous); predatory (when one organism is killed by another); parasitic (when one organism feeds on another without killing it); or scavenger (when an organism feeds on dead organic material).

6. Any of the above types of ecologic relations become economic if they include man in the relationship.

7. While one organism may have an ecologic relation with another, the second has relations with a third, the third with a fourth, etc. Thus we find whole chains and webs of ecologic relationships.

8. When a great many organisms are involved in an ecologic relation, no one of them can become too prosperous, no one will be exterminated. Each thrives enough, no more. The ecologic situation is *balanced.*

9. Balanced conditions are good for all concerned. If the balance is upset by one species, that one species may profit for a short time, but it will suffer in the long run. The calamity it has caused the other organisms becomes its own calamity, for it is ecologically dependent upon the prosperity of all those others.

10. Man has caused more upsets of ecologic balance than any other creature. Epidemics, which are conditions of upset balance, have been caused time and again by man's ruthless destruction of balanced conditions in nature.

DEFINE

Ecologic relation
Inorganic
Organic
Sexual
Threptic
Social
Symbiosis
Predatism
Prey
Parasitism
Scavenger
Saprophyte
Economic
Ecologic chain
Balanced conditions
Epidemic

PROBLEMS

1. In addition to the cases given in this chapter, give illustrations of the following types of relations from your own observations of plants or animals: Symbiosis, parasitism, economic relations, threptic relations, predatism.

2. How many scavenger animals do you know? List them.

3. A tree blew over in a storm. What other plants and what animals might be directly affected as a consequence?

4. How many things (organisms or inorganic conditions) might affect an English sparrow in its lifetime? List them.

5. How many other organisms might be directly affected by the English sparrow?

6. Take any one of the organisms listed in the answer to 5, and show what other organisms it might affect ecologically. Similarly take an organism from this last list, and show its relations. Can you make a drawing, showing this much of the chain and web of relationships?

7. Which is apt to be more regular and symmetrical in shape, the root system or the stem system of a plant? Why?

8. Give definite cases of human interference with the ecologic balance in your own or a neighboring state.

9. Why is it that man has not been more careful not to upset the economic balance in nature?

10. Would it be a better or a worse place in which to live if all the rodent pests (mice, rats, rabbits, ground-squirrels, etc.) were exterminated from your state? Give the arguments on both sides of this question.

11. Which of the subjects taught in your high school are really studies in ecology?

12. Why is it that all the ecologic subjects in your school are not included in a biology course?

13. Is it desirable that students study biology before they take any of the ecologic studies in school? Be prepared to debate your answer.

14. Colleges and universities usually have departments of Economics. Find out what subjects are studied in such departments. Are all of these subjects ecologic? Prove it.

15. List as many instances as you can find of symbiosis.

16. List all of the predatory animals that you know.

17. List all of the scavenger animals that you know.

18. Remembering your physiology, explain why scavengers are so few among the animals.

19. Make a list of the sorts of places (*e.g.*, as in the depths of the ocean) where green plants cannot grow. In each case, explain why.

20. What are the ecologic conditions in caves?

21. What enemies of plants live in the soil?

22. Of what ecologic importance are earthworms? Darwin wrote a whole book on the subject.

23. What climatic conditions are the best for man to live in? The answer is debatable.

24. Give specific instances of ecologic relations that are dependent on man's recently acquired ability to fly by airplane.

CHAPTER XXX

EPIDEMICS

Every now and again some organism goes on a rampage, prospers in its villainy, and becomes the all-important creature of the moment. Perhaps it is a plague of locusts, perhaps it is witch grass, ragweed, or a cabbage worm that is ruining our gardens, or a scale insect that is killing our fruit trees, or a disease organism that suddenly attacks our very persons. In any case, the species is epidemic, in more than its usual abundance. Something has upset the balance of nature, the pendulum is swinging all to one side, and for a time everything seems to work in favor of the unruly plant or animal. It is, to say the least, very uncomfortable for the other inhabitants of the region.

Epidemics have always seemed mysterious to man. When lice and flies and death (due to some disease organism) were suddenly rained onto them, the Egyptians of Biblical times allowed and then begged their Hebrew slaves to leave the land. When the terrible black death swept through Europe centuries ago, the superstitious folks of the day thought they saw the work of witches and devils. Today, when a new invasion of insects injures the farmer's crops, he may consider it a necessary evil and think it useless to investigate further.

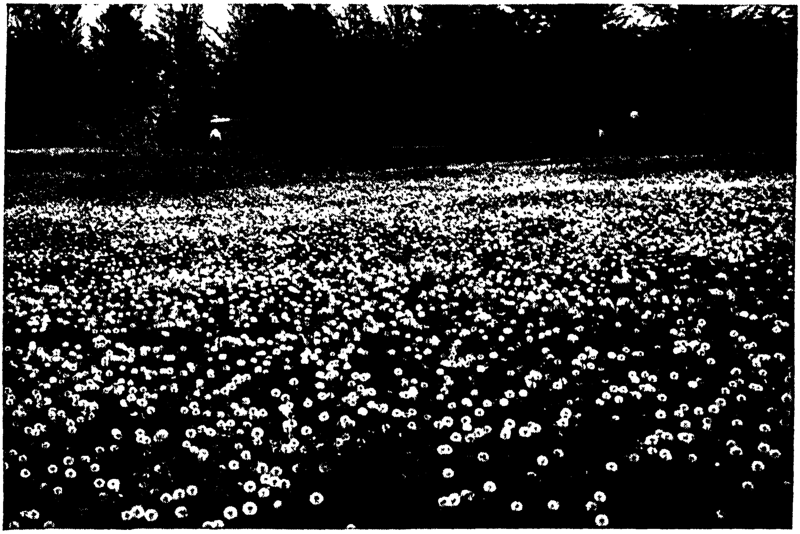
But epidemics are fairly explainable if we understand the nature of a biologic balance of things. The sudden appearance and as sudden disappearance of the pest is not so real as it seems. There is a science, an exact knowledge of the way in which epidemics originate and proceed. If more people shared this understanding of epidemics, we might be able to control more of them.

Copyright Amer. Colony Photog., Jerusalem

FIG. 296.—THE LOCUSTS ARRIVE!
An epidemic in Palestine, 1915.

The Causes of Epidemics

There are two chief causes of epidemics: the nature of the species, and a change of ecologic conditions. These must operate together to bring about an epidemic. It is much as with a match stick. Its nature is such that, of all the articles in the house, it is most likely to produce a fire; but it never does burn until a change of conditions is established.



Courtesy U. S. Bur. Plant Industry

FIG. 297.—DANDELION SEED ENOUGH TO PLANT SEVERAL ACRES
A plant well equipped to become epidemic.

The Nature of the Species.—Some organisms have in their very natures, in their structures and their physiologies, the ability to become epidemic; others could never become so under any condition.

Plants that produce long, tough roots, and an abundance of seeds, that have special structures for scattering their seeds, that have special means of reproducing without seeds (as by bulbs, roots, or cuttings), and that do not require special soils or special light or moisture conditions—such plants are the ones most likely to become superabundant. Dandelions, crab grass, thistles, and plantain are among such well-equipped weeds. The majority of the flowers of the woodlands require such special environments for growth, and reproduce so restrictedly, that they are not likely ever to become bothersome in any place.

The animals that become pests are very often general feeders, finding sustenance on any number of things as they are available. Ants are successful for this among other reasons. The gipsy moth, the Japanese beetle, the European corn borer, many of the grasshoppers, cutworms, white grubs, and plant lice are among our serious insect problems because they are no more restricted to particular kinds of food than the rats or mice that invade our homes.

Changed Conditions.—Given the specific nature to become epidemic, the organism merely needs to wait until changed conditions of some sort provide the time most favorable for its prosperity. Thus, body lice ("cooties") become most abundant among civilized nations when war, poverty, or famine bring congested living conditions and discourage the sanitary care of clothing. Changes in weather conditions, in shelter, food, and enemy conditions, and in geographic locations, will account for most epidemics.

Sudden and severe changes are very likely to produce epidemics. Unusually severe winters, severe floods or droughts, forest fires, a large number of pioneers arriving in a new country, or the sudden coming of wealth or poverty to a region are all breeders of pestilence. Often the same changes developing over longer periods of time do not bring disastrous results, for then all the organisms involved are able to keep themselves adjusted in continuously balanced relations.

The change of conditions that most often starts an epidemic is the destruction of the natural enemies of some possible pest. Many weeds and insects have become pests in this country because they were imported from foreign countries without their native parasites and bird controls. Parasitic and predatory animals are of great value in maintaining balanced conditions, and any change of conditions that reduces their numbers or their efficiency will let the pests that they have hitherto controlled prosper unduly.

The Kaibab Deer.—This relation of an epidemic to the predators in the region is well illustrated by the deer on the Kaibab Plateau in northern Arizona. The Kaibab is an elevated tableland of limited extent, surrounded on three sides by impassable river canyons, and on the fourth by a desert. The mammals living on the Plateau are thus completely isolated from other forested areas, and the ecologic balance on the Plateau must be maintained without consideration of any other region. When the Kaibab was established as a game preserve in 1906, the hunting of deer was prohibited and thousands of their natural enemies, cougars, coyotes, wildcats, and gray wolves were killed. The deer, thus protected, began to increase at an astounding rate. The natural food supply was, however, limited, and the increased numbers of the deer soon reduced the original supply to one-tenth of what had been there in the first place. In spite of recent hunting of the deer, and government provision of winter food for the animals, great numbers of them have starved to death and the food supply is still shrinking. The removal of the predatory animals started what is truly an epidemic of deer which may yet end where many epidemics end—in the starvation of the over-prosperous species.

Native Pests

Some epidemics are caused by species native to the region in which they become over-prosperous. Ground-hogs (woodchucks), some of our squirrels, rabbits, and ground-squirrels are such native American animals that flourish unduly. In all of these cases the epidemics have been brought about by the destruction of the natural enemies of the pests.

Another item favoring the increase of native pests is the abundant food supply furnished by the crops which man now cultivates. Blackbirds and crows are probably more abundant now than formerly because the great grain fields of today produce such food as was not to be found when the red man roamed this continent. May beetles or June bugs, the larvæ of which, commonly called white grubs, feed on the roots of grasses, find our lawns, pastures, hay, and grain fields much more favorable to their increase than the forest-covered areas of North America of a century or two ago. The chinch bug, important pest of corn and wheat in the Middle West, did not become epidemic until those crops were widely cultivated. Locusts, wire-worms, tent caterpillars, and cucumber beetles are also native insects flourishing because of present-day conditions. Certain plant pests, like milkweeds, goldenrods, ironweeds, and some of the wild lettuces, are abundant for similar reasons.

FIG. 298.—NATIVE PESTS

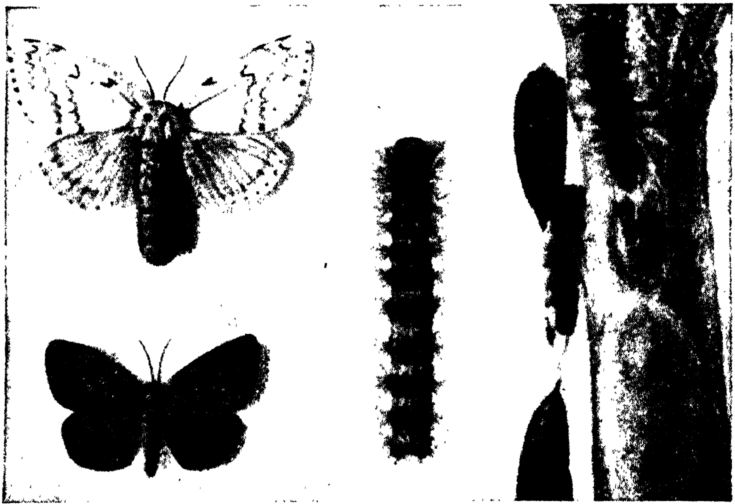
Due to the destruction of their natural controls (predatory birds and mammals), cotton-tail rabbits are becoming more abundant close to civilization than in open country.

Foreign Pests

The list of native pests is, however, smaller than the list of pests that have come to us from other shores. The imported things are strikingly harmful compared with related species

Courtesy Amer. Mus. Nat. Hist.

FIG. 299.—THE IMPORTED CABBAGE BUTTERFLY



Courtesy U. S. Bur. Entomology

FIG. 300.—ANOTHER IMPORTED PEST, THE GIPSY MOTH
Egg cluster, larvæ, pupæ, adult female (white), and male (yellow)

that are native to America. The English sparrow is a nuisance, while our American sparrows are distinctly beneficial. The European rats and mice are the daily curses of our communities, but our native rats and mice are hardly known to any but the special students of animals. The imported dandelions, plantains, hawkweeds (devil's paint brush), chickweeds, smartweeds, buttercups, and pigweeds are among the commonest of our weeds, while the native species of the same families are relatively rare, many of them being found only in the wilder woodlands.

The imported cabbage butterfly is the species familiar to most of us, for the intruder has thrived more than the native butterfly whose larvæ feed on cabbages. The Colorado potato beetle, spread into the Eastern United States from the Rocky Mountain country, has replaced the "old-fashioned potato bug" of our grandparents' day. The European species of cockroaches are quite too familiar throughout our land, and tropic roaches are invading the Southern United States. The list of foreigners includes the cotton boll weevil, the asparagus beetle, the elm leaf beetle, the Japanese beetle, the pantry beetles and carpet beetles of our households, the codling moth, the gipsy moth, the brown-tail moth, the European corn borer, the house fly, the San José and other scale insects, many kinds of plant lice, and other important pests.

Freedom from Natural Controls.—The main reason for the prosperity of an introduced organism is its freedom from the natural controls that held it in check at home. It takes many years for native birds, parasitic insects, and other control organisms to reduce the newcomer to its proper place in the balance. The brown-tail moth, accidentally brought here about forty years ago, soon became a severe pest in New England and lower Canada; and only ten years ago did it begin to decrease because of the natural enemies that had been introduced. It will take much more than thirty years to overcome the epidemic abundance of some other imported plants and animals.

Farming Methods.—Many pests appear to thrive more in America than in their native homes. The differences in farming methods encourage this. In Europe each farm is small, is carefully cultivated, and grows a number of different crops. In America, the farms are so large they cannot be carefully attended to and, what is more disastrous, it often happens that only a single crop is grown on the farms of a whole great stretch of country. In the Middle West it may be corn, farther northwest it is wheat, in parts of the South it is often cotton, elsewhere in the South it may be sugar cane, while in Florida and Southern California there are citrus fruits (oranges, lemons, grapefruit) to supply the abundance of food just suited to the taste of some particular invader. Why shouldn't the enemy flourish?

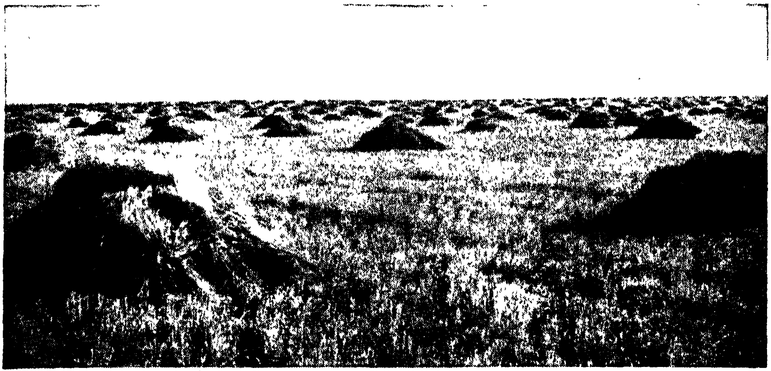

Courtesy U. S. Bur. Plant Industry

FIG. 301.—EXTENSIVE WHEAT GROWING IN MONTANA

Although Europe has sent America so many pests, America has contributed few to Europe. No doubt American weeds and insects are carried to the Old World often enough by accident, but they fail to become established there. Balanced conditions are probably well established in the long-cultivated parts of Europe, and it seems difficult for invaders to disturb things there.

Descriptions of Epidemics

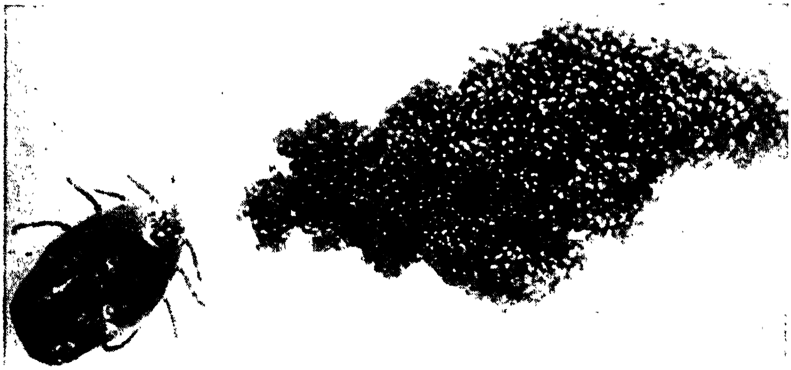
Whatever the organism involved, an epidemic usually starts gradually, spreads rapidly, reaches a dramatic climax, and ends abruptly. Often it is followed by a succession of other epidemics, each of which is less severe than the preceding.

Gradual Start.—Usually we do not realize the abundance of the enemy hosts until the climax of the invasion is at hand. But probably all epidemics start gradually, so gradually that we at first overlook them. Thus it was that within four months of its first discovery in America, a certain species of fly was found at twenty-eight localities spread over Connecticut, New Jersey, New York, Massachusetts, and Quebec. Undoubtedly the insect had been there for several years, but we failed to give attention to it until it had become widespread and common.

That epidemics start gradually is also borne out by the history of the gipsy moth in America. This insect while a caterpillar feeds on the leaves of many kinds of trees and bushes, and it has done millions of dollars' damage in New England. The first specimens were brought by a silk grower to this country from Europe. They accidentally escaped from his house in Medford, Massachusetts, in 1870, and the fact was publicly announced. Although no one again noticed the insect for a while after that, it must have industriously increased its numbers, for by the end of twelve years it had become a local pest. It was not, however, until twenty years after the introduction that the town as a whole realized its problem; and then, when search was made, the moth was found to have spread into thirty townships, in none of which had it attracted any attention while it was gaining its foothold. Soon the whole state was aroused, but not before the full force of the epidemic was upon it. The insect is still abundant and is still spreading its range, and many millions of dollars have already been spent in an attempt to control it.

Rapid Spread.—Epidemics, once started, spread rapidly.

This is chiefly because organisms multiply geometrically from generation to generation. A pair of individuals that has, for instance, five pairs of offspring might have twenty-five pairs of descendants in the next generation, and 125, 625, 3,125, 15,625, and 78,125 in the following generations. A bit of mathematics will show how quickly a million might be reached.



Courtesy U. S. Bur. Entomology

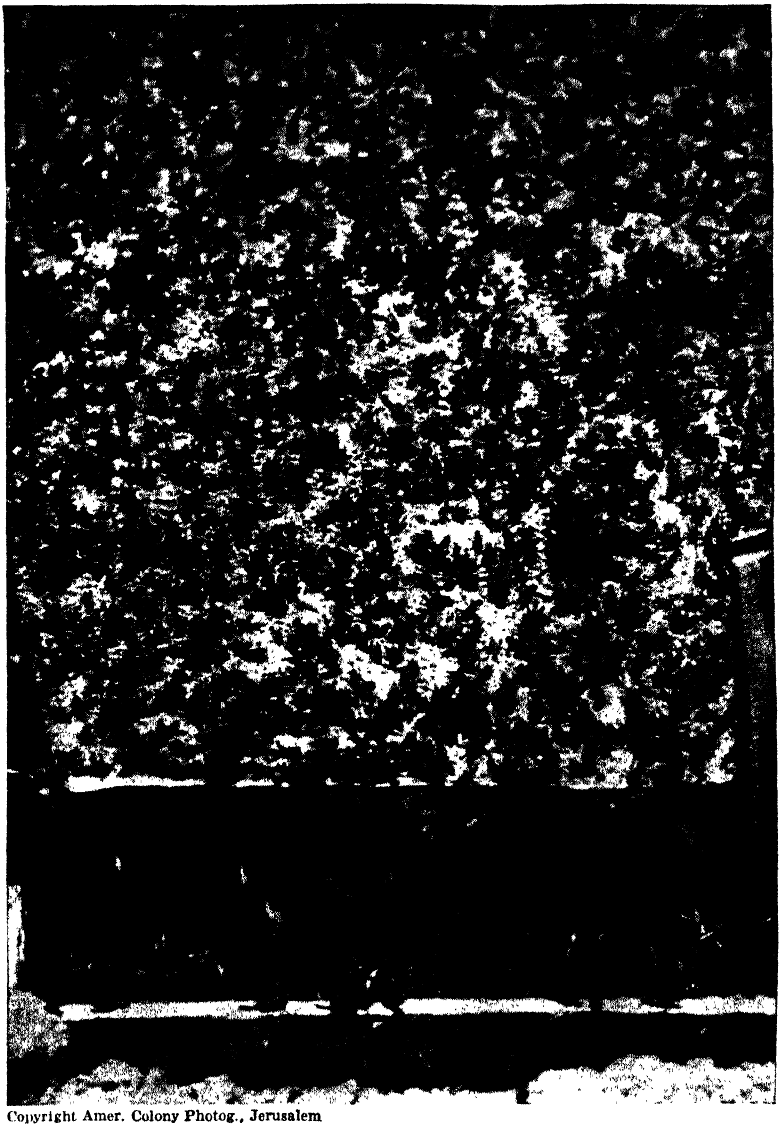
FIG. 302.—A TICK AND ITS EGGS
Illustrating the possible rate of reproduction.

Notice how much more rapidly the numbers increase with the later generations.

The rate of reproduction of many organisms far exceeds the numbers employed above. In 1916 the entire search for the Japanese beetle in New Jersey yielded but a dozen insects. Three years later the species had so spread that a single man might have collected 20,000 beetles by hand in a day.

Sometimes organisms do their multiplying in one place and then migrate to other regions to do their damage. That is the history of the grasshopper and cricket plagues that have descended upon man time and again in his history.

Abrupt Ending.—More real than the sudden climax of an epidemic is its usually abrupt ending. It is not until the para-



Copyright Amer. Colony Photog., Jerusalem

FIG. 303.—LOCUSTS EVERYWHERE
In the epidemic in Palestine, 1915.

sites and other natural enemies of the pest have reached their epidemic form that they can work anything like a notable reduction of the harmful species. As the controls, increasing geometrically, rapidly reach their climaxes, the pest is as rapidly removed from our attention.

But now the controls, with nothing on which to live, become reduced in numbers. This allows the pest to flourish again! Thereupon starts a see-sawing of after-epidemics, first of the pests, then of the controls. We do not notice the epidemics of the controls, but we do see the periodic re-occurrence of the other organism. In this succession, each epidemic is less severe than the preceding one. The pendulum, swinging from side to side, gradually slows down toward the midpoint. The epidemic species is finally reduced to its proper place among other organisms, not to become bothersome again until there is some new disturbance in the balance of nature. Whatever creatures are involved, this is the picture of all epidemics.

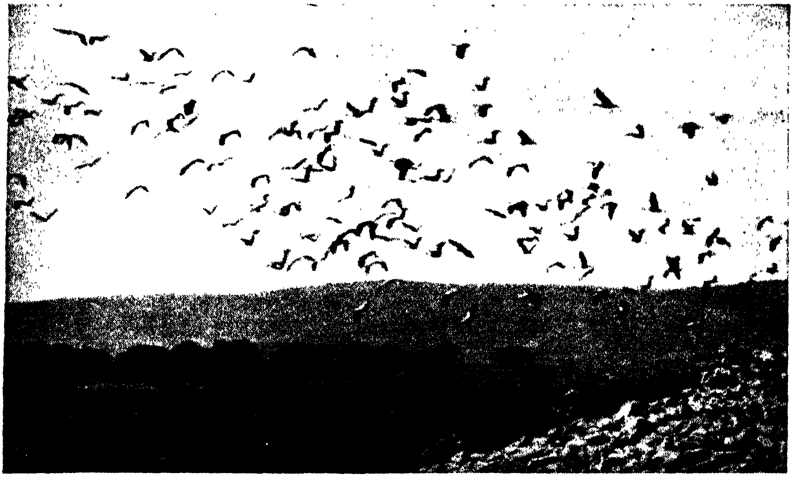


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FIG. 304.—AN EPIDEMIC OF BIRDS AS CONTROLS
Following the epidemic of locusts in Palestine, 1915.

Prevention of Epidemics

Obviously, our first interest will be to prevent new epidemics from starting, to prevent new disturbances in the balance of things.

Conservation.—The first step in the prevention of epidemics must be the prevention of any great change of conditions, such as would upset the ecologic balance of things. This means the conservation of our present supply of natural resources. Our wild plants and animals should in general be protected under natural conditions. Wherever forests still stand they should be preserved, or lumbered in such a way as not to completely strip the area. Birds or mammals should not be killed except those few species which experts advise us are pests, and those game species which may safely be hunted without seriously reducing their numbers. Probably the wholesale destruction of any organism by extended hunting or poisoning or by burning over large areas of country, is never justified.

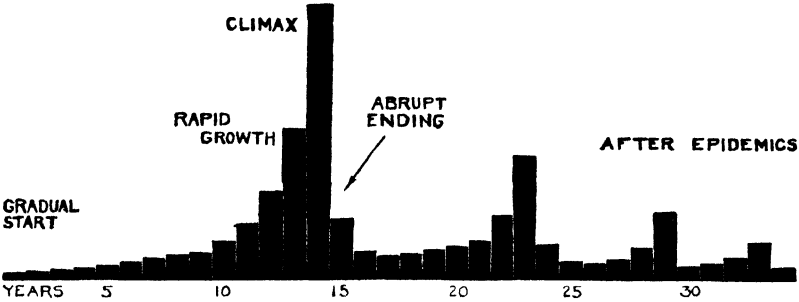
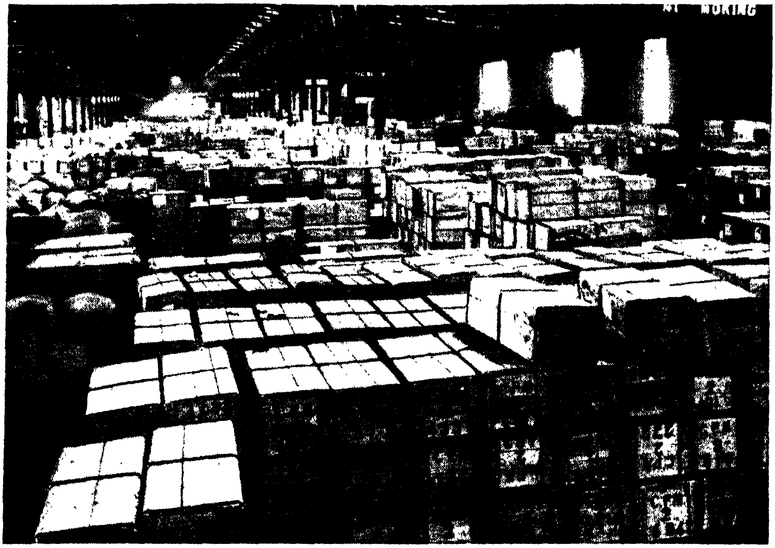


FIG. 305.—COURSE OF A TYPICAL EPIDEMIC

Quarantines.—The other important step in the prevention of epidemics is the provision that living plants or animals may not be carried from one region to another except under wise precautions. Remember that introduced organisms make the worst pests!

The United States Department of Agriculture, with authority from Congress, has made laws and established quarantines which forbid the transportation of certain plants and animals except on permits for special reasons. Nobody for a moment expects that under these laws it will be possible to prevent every invader from entering. The Federal inspectors realize the inadequacies of their work better than anyone else; but they do prevent hundreds of pests from being spread over our land each year.

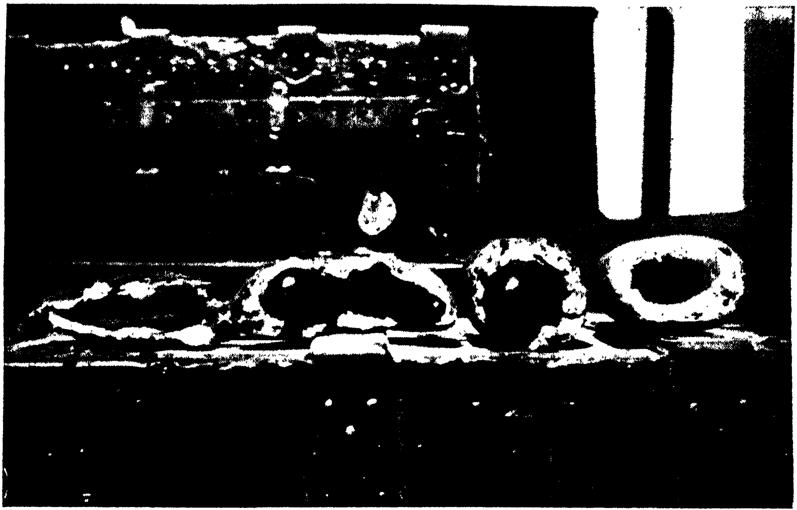


Courtesy Bur. Plant Quarantine

FIG. 306.—18,000,000 NARCISSUS BULBS FROM FRANCE
Any one of which may be bringing insect pests to our shores.

Quarantines would accomplish more if more of us would coöperate. Mexican fruits are brought across our southern borders chiefly by American tourists. Many people oppose the ruling that so-called Dutch bulbs may not be imported. In many cases there has been active resistance of the men who inspect automobiles in quarantined regions. The lone inspector on the foot-bridge at El Paso, Texas, where 10,000 persons may cross from Mexico in a single day, finds that infested fruit is often smuggled in baggage, inside of clothing, or even baked into loaves of bread; and other persons wade the Rio Grande where no inspector awaits them.

We all may help keep this country free of new epidemics by supporting the quarantines and the men who are protecting us against invasion.



Courtesy Bur. Plant Quarantine

FIG. 307.—MEXICAN FRUITS SMUGGLED IN BREAD

SUMMARY

1. An epidemic is an upset of ecologically balanced conditions in which one organism thrives unduly, working great damage on other organisms. Epidemics have always seemed mysterious and unexplainable, but they are as explainable as any other biologic event.
2. The plant and animal species which most often become epidemic are those that have special means of reproducing and spreading, that are general feeders, and that do not need special conditions for their development.

3. Such species become epidemic only when there is some change of conditions (most often the removal of their natural controls). Sudden and severe changes are almost certain to produce epidemics.

4. The species that have become epidemic include some native plants and animals. The removal of their natural enemies, and the widespread cultivation within the last century of crops which furnish good food for the pests, explains why we have more native pests than our forefathers had.

5. Most of our epidemic organisms are foreign pests recently imported into this country. Here they are free from the controls which they had in their native homes. Here also our farming methods are more favorable for the increase of a pest.

6. Epidemics start gradually, even though their start is usually overlooked. Epidemics spread rapidly because living organisms multiply geometrically. Epidemics end abruptly because the controls (parasites, predators, etc.) find so much food that they become epidemic. When this happens the first organism may suddenly be all but exterminated. Then the control is starved, and the pest has a chance again to become mildly epidemic. Thus a series of after-epidemics may follow, each epidemic becoming less severe than the preceding because the pest and its control more nearly catch up with each other.

7. The prevention of epidemics requires the preservation of natural conditions without upsetting the ecologic balance. The wholesale destruction of any native plant or animal is rarely justified.

8. In addition, quarantines are established to prevent the importation of new pests from foreign countries, or the carrying of a pest from one part of our own country to an uninfested area.

DEFINE

Epidemic
A control (in ecology)
Pest
Quarantine
General feeder

PROBLEMS

1. How many organisms may be said to be epidemic right now in your part of the country?

2. How many reasons can you give for the dandelion so often becoming epidemic in America?

3. How many reasons can you give for the house mouse becoming epidemic?

4. Start with one pair of house flies. Assume that it and each pair in the succeeding generations has sixty pairs of offspring, and that a new generation appears on each of the following dates. Assume that every individual lives to reproduce (though this of course does not happen in nature), and then dies. Can you show how many flies there would be on each of these dates: April 15? May 10? June 8? June 30? July 19? August 8? August 28? September 10?

5. Make a diagram showing the size of the above fly epidemic on each of the above dates.

6. Is it more important to prevent the breeding of flies in April, or to "swat" them in September?

7. Have you ever had any experience with inspectors on some quarantine? If so, describe it.

8. American farming is described as extensive and specialized; European, as intensive and diversified. Explain what this means. What are the advantages and disadvantages of each method?

9. Review the chapter on Immunity to Disease, and explain it in terms of epidemics.

10. Make a list of all the organisms which you have ever heard of becoming epidemic. In each case, name the chief adaptations (advantageous structures, method of distribution, etc.) which account for the fact that these are the creatures that become epidemic.

11. Have you ever heard of after-epidemics occurring in your lifetime? Tell about them.

12. Name some human diseases that do more damage in regions where they have been introduced than they do in their original homes.

13. Make a list of some plants and animals which you know, which grow wild in your part of the country, but which were not here before white man came.

14. In regard to the importation of plant products from foreign countries, would it be better to have American officials inspect in the foreign countries or at the American ports? Try to find out what our government officials now think of this (since 1937).

15. What is a weed?

16. In what respects might airplanes prove more dangerous than steamships in upsetting ecologic balance? Why are such problems easier to control with airplanes?

17. If man were not in existence, do you think there would be any or as many epidemics?

CHAPTER XXXI

PEST CONTROL

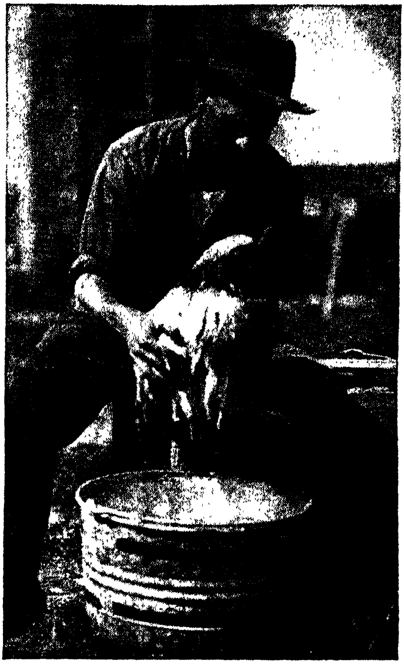
After an epidemic is started there is nothing to do but to fight it with the best means at hand.

Artificial controls, such as spraying for insects or the weeding of gardens, are the most available ways of attacking pests, but they are usually only temporary in their effects. Complete extermination of the offending species, while a very attractive proposition, is not often possible. Although temporary means of control have to be used to meet the immediate attack of the enemy, we cannot hope for peace until we have so encouraged natural forces as to re-establish a balanced state of affairs in the region. With these things in mind we shall examine in more detail the several methods of pest control.

Artificial Controls

We speak of certain means of control as artificial in contrast to the biologic controls which aim primarily at re-establishing balanced conditions. The artificial controls are those ways by which man may use his hands and his tools to attack the pest.

Direct Attack.—Sometimes he gathers the pests by hand, a method which may be effective against large and conspicuous insects (like the potato beetle and the tobacco and tomato worms), or against insects which live in conspicuous places (as cotton bolls infested by weevils). Weeding by hand is still the most generally practiced control of plant pests in small gardens. Lights are used to attract and trap moths, screens are regularly depended upon to keep insects out of our houses, sticky paper and swatters are effective against limited numbers of house flies, traps help control rats and mice in houses and barns, and a scythe and fire may be employed on weed patches or crops infested with some fungus disease. Such methods of control are easily applied, but they are effective only when repeatedly employed, and then only over more or less limited areas.



Courtesy C. R. Cleveland, Purdue Univ.

FIG. 308.—CONTROLLING POULTRY PARASITES

By dipping the hen in a poison solution.

Poisons.—These often work destruction faster than direct attacks, and may be used on an indefinitely large scale. Sometimes they are intended to injure the living tissue of the pest or to make conditions unsuitable for the development of the pest. Thus, Bordeaux mixture is the standard spray for rusts, mildews, and other plant disease organisms; and common salt or copper sulphate solutions are effective against certain weeds.

Stomach Poisons.—For animal control, stomach poisons may be sprayed over the food of the pest. Lead arsenate is the best spray or dust to put on plants infested by chewing insects; and in open country arsenic baits are effective against rats, prairie-dogs, ground-squirrels, and other mammals, as well as for such insects as grasshoppers and cutworms.

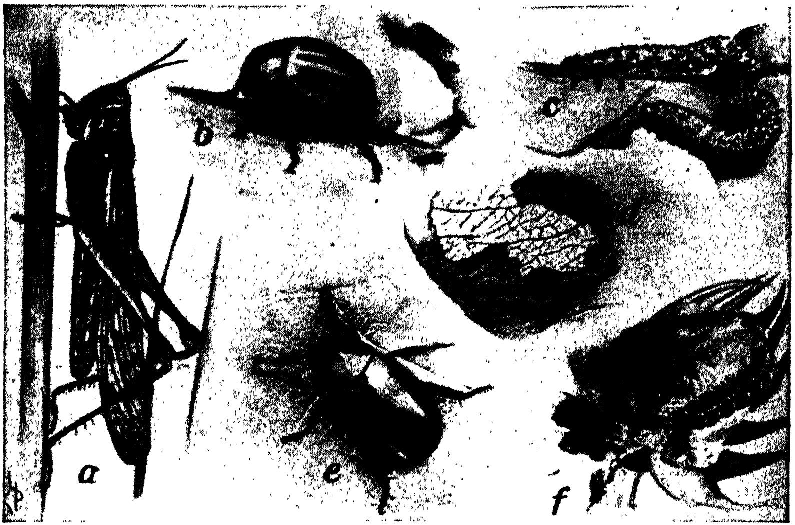
Contact Poisons.—Many insect sprays or dusts are poisons the vapors of which kill as they enter the air-tubes of the pests. Such contact poisons must be so well spread that they cover every breathing pore of every insect. This is the way to fight plant lice, scale insects, and all true bugs. Such insects have sucking mouth-parts that suck sap; they do not chew and take portions of the plant tissues into their stomachs, and consequently they would not be poisoned by lead arsenate.

Courtesy U. S. Bur. Entomology

FIG. 309.—DUSTING TO CONTROL GARDEN INSECTS

Lime-sulphur, kerosene-soap emulsions, and nicotine (tobacco) preparations are the commonly used contact poisons. Oil thoroughly spread over the surface of stagnant streams or ponds acts as a contact poison for mosquito larvæ.

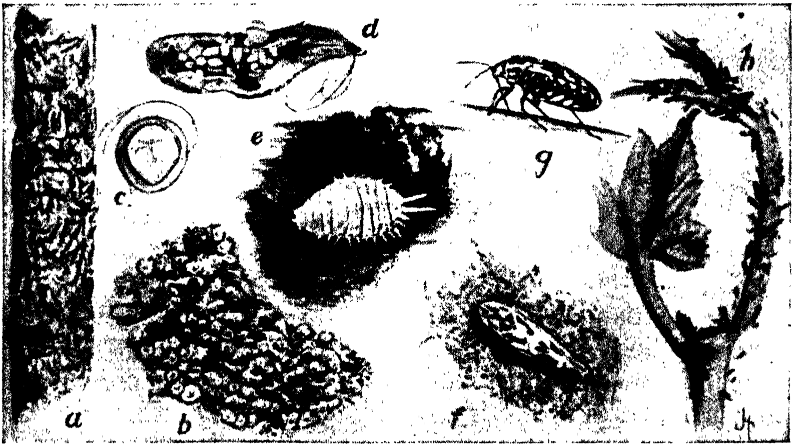
Repellants.—There are a few substances which are so disagreeable to insects as to discourage them from ever attacking the protected spot. For clothes moths and some other household pests, naphthalene or gum camphor is a better repellant than moth-balls, but better still is paradichlorobenzene ("P. D. B."), a powdery material that is commonly sold in drug-stores for the control of insect borers in the roots of trees.



Courtesy U. S. Bur. Entomology

FIG. 310.—INSECTS WITH BITING MOUTHS

a, grasshopper; *b* and *e*, beetles; *c* and *d*, sawfly larvæ; *f*, caterpillars. Use stomach poisons for these.

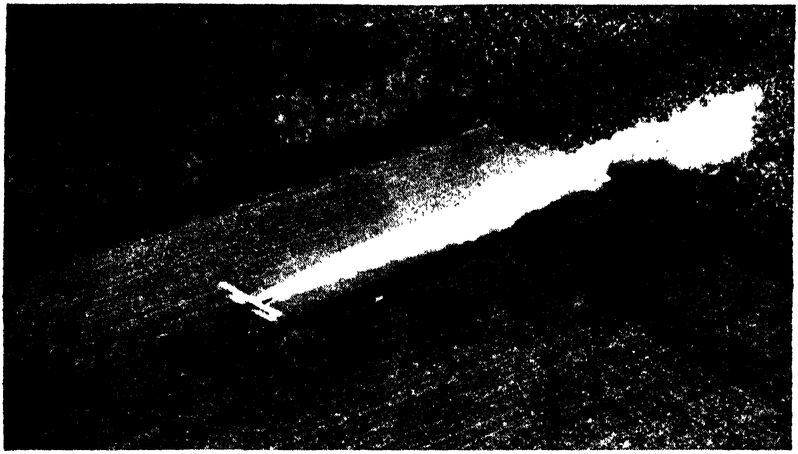


Courtesy U. S. Bur. Entomology

FIG. 311.—INSECTS WITH SUCKING MOUTHS

a to *e*, scale insects; *f*, leafhopper; *g*, plant-bug; *h*, plant lice. Control these with contact poisons.

Fumigants.—These are gases that kill when organisms breathe them. Carbon bisulphide and hydrocyanic acid gas are the best fumigants against insects, rats, mice, prairie-dogs, and ground-squirrels, but these gases are so deadly that they should never be used except by a specially trained person. Carbon tetrachloride is a safer but less effective fumigant. Sulphur or nicotine fumes may also be used. Merely keeping the temperature of a room at 130° F. for three hours will usually kill the insects in the place, and this is one of the easiest ways in which to fumigate for household insect pests.



Courtesy U. S. Bur. Entomology

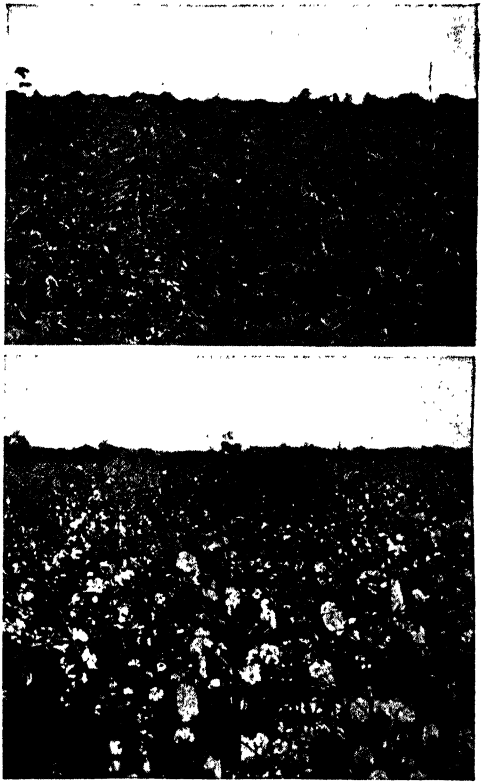
FIG. 312.—AIRPLANE SPREADING A POISON DUST TO CONTROL COTTON INSECTS

Most of the stomach poisons, contact poisons, and fumigants are dangerous to handle, and they may kill animal stock, or they may injure the plants that are being sprayed if they are not carefully and properly used. No one should attempt to utilize them unless full directions can be obtained when the materials are bought, or unless the advice of some experienced person is available.

Cultural Controls

Sometimes the injury from an epidemic organism may be reduced merely by growing crops under conditions favorable to them but unfavorable to the pests.

Healthy Crops.—Crops that are liable to attack should be kept in especially healthy condition. One blow may kill a weakling, but healthy individuals may come through several attacks without suffering greatly. Well-pruned, properly planted, properly cultivated fruit trees escape the fatal results of many insect and fungus attacks. Poorly developed and stunted trees suffer from every pest that comes along, and they become the breeding places of diseases for the whole community. A stunted row in a truck garden, a rotting apple in a basket of fruit, or an ill-kept house in a community is a source of danger to all its neighbors. The energetic, intelligent farmer or housekeeper will have none



Courtesy U. S. Bur. Entomology

FIG. 313.—CULTURAL CONTROL OF COTTON BOLL WEEVIL

Early planting (below) escapes more of the weevil attack than the later planting (above).

of those things, and thereby keeps free of pests without deliberately planning to do so.

Season of Planting.—Farm crops are sometimes planted earlier or later than usual in order to avoid the season when some particular plant or animal pest is most active. An early planting of cotton escapes some of the boll-weevil attack. Late planting of wheat reduces the damage from Hessian fly. County agents, or experts at the Agricultural Experiment Stations, can advise how such cultural controls may be applied to the problems of any particular region.

The rotation of crops, originally practiced because of soil and plant food considerations, results in each community growing a variety of things each year, and then the whole region cannot suffer complete loss if some epidemic ruins one of the crops. The single crop method of farming in America must give way to diversified farming if we would avoid some of our worst problems.

Extermination

Often our attempts at control have been used with an idea of exterminating the pests.

Extermination Is Difficult.—In most cases there seem to be few chances of effecting an extermination. General feeders (rats, gipsy moths, white grubs, Japanese beetles) are always likely to be with us. Organisms that have especially good means of reproduction (as insects that lay an abundance of eggs, and dandelions that are even able to produce seed without fertilization), and organisms that are especially equipped for travel (as strong fliers, and plants that have winged seeds) are pests that are not going to disappear very soon.

Pests that occur in large numbers are not easily brought under control by artificial means. There are not enough of the human animals to wage the war. Millions of hands have pulled dandelions out of lawns without appreciably affecting the world-wide abundance of that plant.

Human abilities are, after all, limited. Human eyes and patience tire too quickly to locate such small things as the insects that bother us. Large crews of trained men have tried to rid parts of New England of its gipsy moth infestation. They have worked hard to locate the eggs that might be hidden in the cracks and crevices. They have sprayed burning oil against the stone walls, and cut and burned the underbrush where the young larvæ were developing. They have climbed the trees, hunting for the eggs. They have placed sticky bands on the tree trunks to prevent the insects from climbing up to feed, and with powerful pumps they have sprayed poisons onto every green thing that might serve as food for the pests. But enough of the insects have escaped to leave the species still important. Certainly its numbers have been much reduced by such control work, and the country is much better off for it, but still far from the fulfillment of the original dream of extermination.

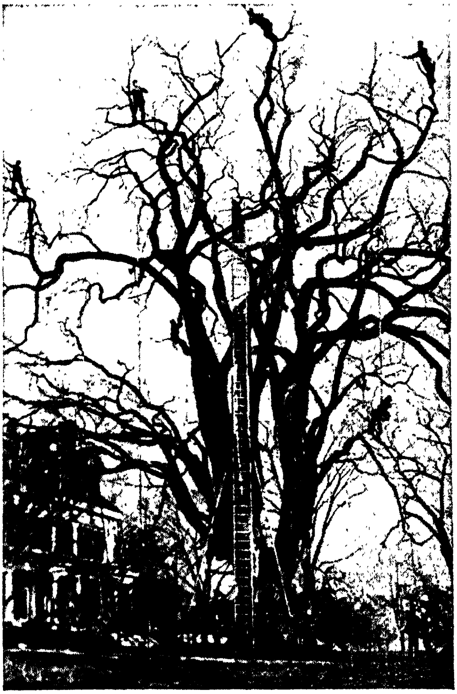
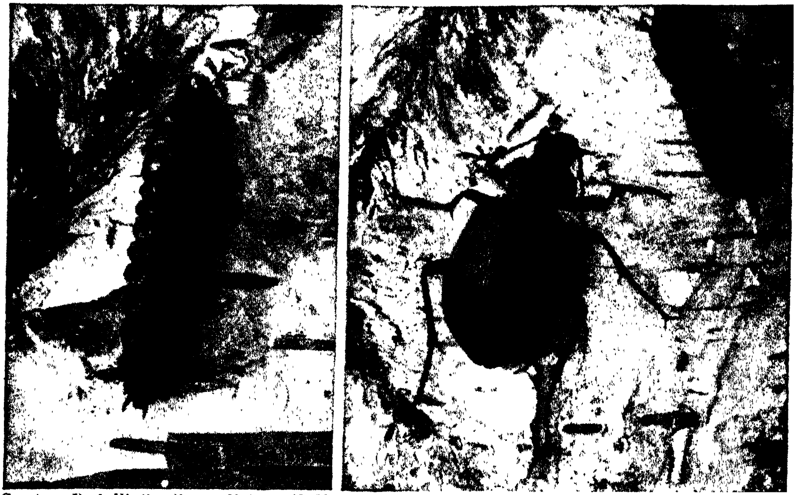

Courtesy F. H. Forbush

FIG. 314.—HUNTING GIPSY MOTH EGG CLUSTERS

Illustrating the difficulty of exterminating a pest.

Extermination Is Possible.—That man can exterminate certain plants and animals is proved, however, by the history of some of the larger mammals and of certain birds. The passenger pigeon once travelled in flocks that darkened the sky, although they are now extinct. Some pests that occurred over only small areas and in small numbers have been exterminated by the standard artificial controls. A pest that is confined to a single species of food plant or to a very particular environment may sometimes be eliminated from a given region. Many badly infested localities have been rid of the yellow fever and malarial mosquitoes because those insects are confined to breeding places of stagnant water, against which places the attack may be confined. The disease organism producing yellow fever has been, in consequence, exterminated from large areas of the world where it formerly flourished. Another disease, smallpox, has been exterminated from countries where vaccination is universal.



Courtesy Prof. W. C. O'Kane, Univ. of N. H.

FIG. 315.—A PREDATORY BEETLE, LARVA AND ADULT
Imported to help control the gipsy moth.

The most dramatic instance of extermination of a major pest comes as a result of the fight made against the Mediterranean fruit fly in Florida, during 1929. The discovery of the pest was made, apparently, before it had become established beyond a central area in the one state of Florida. Millions of dollars were made available, the fruit growers coöperated by destroying most of the year's crop, the people of the state submitted to having the National Guard called out to enforce the quarantine. Florida, surrounded on three sides by water, is well placed to enforce such a quarantine; the semi-tropic nature of the insect may have helped confine it; and other natural agencies may have operated against the pest. Nevertheless, there is no doubt that it was the vigorous and intelligent extermination campaign so promptly put into effect that was responsible for the nearly complete clean-up within five short months, and the apparently complete extermination of the fly within the year.

This happy experience with the Mediterranean fruit fly has served to renew our hopes that other pests may be exterminated if we attack them soon enough after their arrival. Still we should understand both the limitations as well as the possibilities of an extermination program.

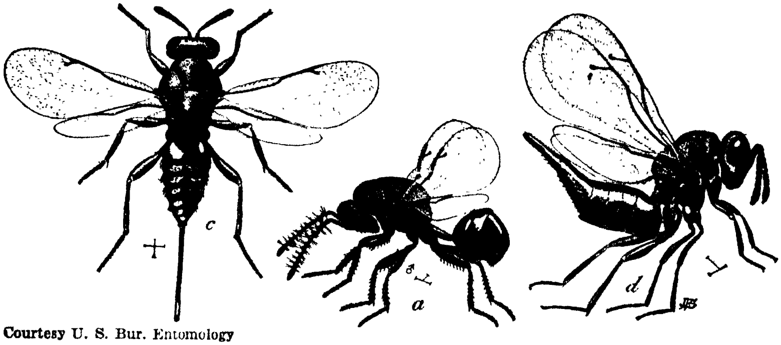
Biologic Control

In biologic (or natural) control man tries to encourage the natural forces that may restore an ecologic balance and reduce the pests to an unimportant place in nature.

History.—The history of biologic control began in 1888, when the fruit growers of California, coöperating with the U. S. Government Entomologist, sent a man to Australia to find the natural enemies of the Australian fluted scale insect that had spread to California and was threatening to kill the orange trees of that state. The lady beetle (ladybug) that was imported as a result of this investigation soon became established in California, and in a few years had reduced the scale insect to comparative unimportance.

Various attempts were made after that to control still other pests, but few of them met with any success. It is only within the last twenty years that renewed determination and greater knowledge are accomplishing other notable results with biologic control. Today the method is proving so promising that most of our foreign insect pests are being studied in their native homes, and hundreds of predatory and parasitic insects have been imported to help control epidemics in America.

Methods.—The first thing done is to discover what far-off land, eastern Europe, China, or Japan, has contributed the invader. Then off to that place goes a group of American scientists. They watch the insect in its native fields, they breed it in laboratories, taking note of all its enemies. Most of them cannot possibly be carried back to America: But sometimes some parasitic insect is found, perhaps hardly larger than a pin-head, that can be obtained in numbers. Eggs, larvæ, pupæ, or adults of the bug fighter are packed into boxes, put into cold storage so they will not die on their long journey, and shipped by fast express half way around the world.

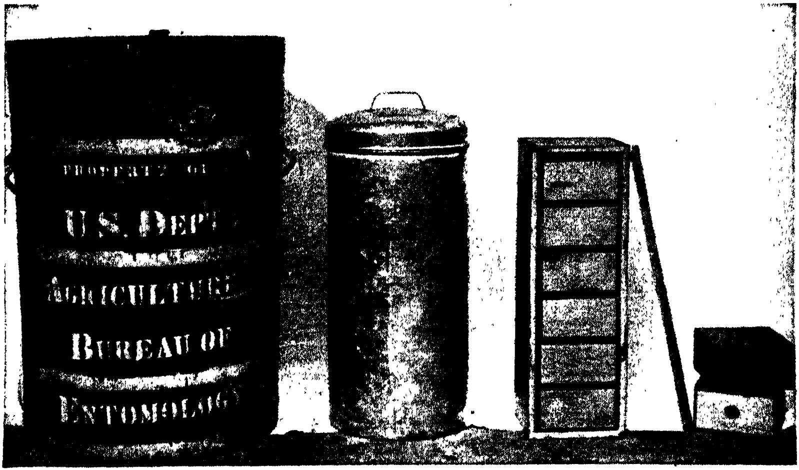


Courtesy U. S. Bur. Entomology

FIG. 316.—PARASITIC WASPS, ENEMIES OF THE COTTON BOLL WEEVIL
Actually smaller than a small ant.

Two-thirds or more of them may, nevertheless, die en route. Those that live are very carefully fed and taken care of in the American laboratories until their numbers have increased enough to warrant releasing them. Then the tiny creatures are let loose by the thousands in the open fields or the wide woodlands.

After this comes a long period of anxious waiting. Will the friendly parasites live and reproduce and multiply in their new home? Many, many of the importations are failures. Often they must be tried again and again. It may be several years later before anybody ever finds a specimen of a pest with an introduced parasite in it. It may be some years more before reports finally begin coming in from scattered localities that the parasite lives. It lives, and is spreading over the country! In succeeding years it will become abundant, and some day it may be a great asset to our land.



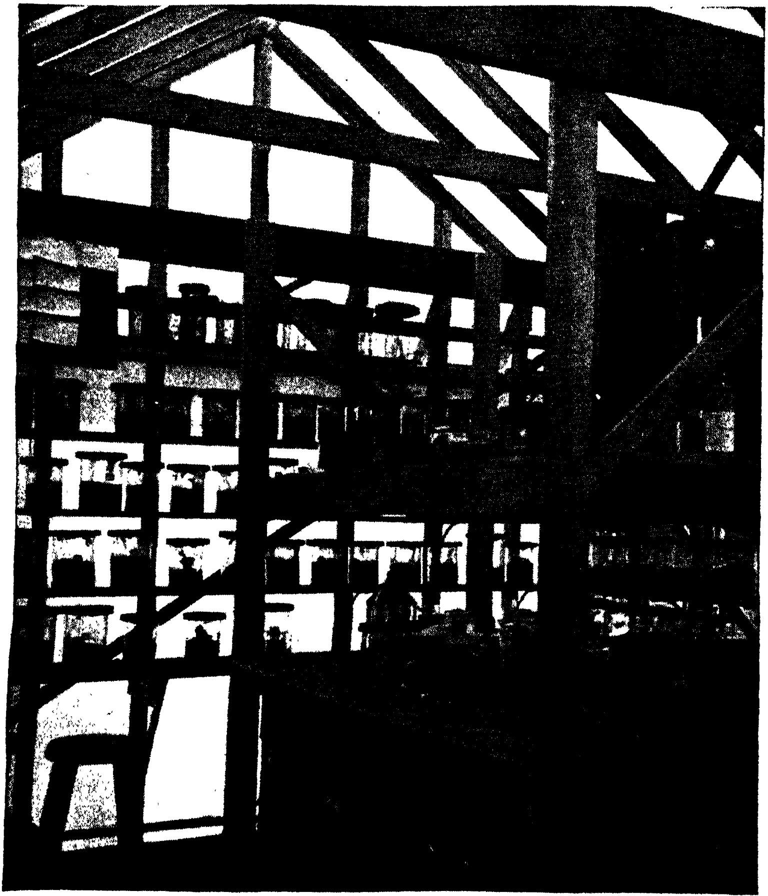
Courtesy U. S. Bur. Entomology

FIG. 317.—COLD STORAGE EQUIPMENT FOR SHIPPING INSECT PARASITES

Government scientists are beginning to learn a good deal about this delicate job, and the number of successes is increasing yearly. Parasitic insects, predatory insects, and the organisms of insect diseases are being brought into our country. Sometimes a single kind of control does the work. Sometimes a larger number of controls have to be imported. Forty-six species have been introduced against the gipsy moth alone. Of these, fifteen are now established here.

Of course, any program of biologic control must be extended over many years and must be employed on a very large scale.

Only experts working under state or national governments can deal with such things. You and I, plain citizens, need merely to understand the principles upon which such work is based and to encourage the men who are conducting the campaigns.



Courtesy U. S. Bur. Entomology

FIG. 318.—AN OUT-DOOR LABORATORY

For raising parasites of insect pests.

Vertebrates as Controls.—The vertebrate enemies of pests are also important controls, but the importation of those animals has usually proved disastrous. It is apparently wisest and certainly very profitable to depend upon our native vertebrate friends, and to protect and to encourage them. Fish may be placed in streams to destroy mosquito larvæ and other aquatic pests. Frogs and toads, skunks, moles, and shrews are all insect-feeders that deserve protection. Practically all of our birds are beneficial as weed- and insect-destroyers, and everything should be done to protect them against their enemies (guns, cats, red squirrels), to provide places for their nestings, and to give them water and food in severe seasons.

Courtesy N. Y. Zoological Soc.

FIG. 319.—THE SKUNK
A vertebrate enemy of insects.

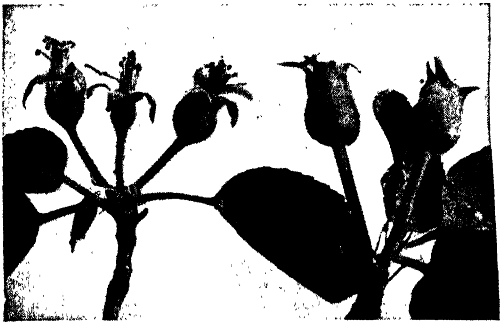

Courtesy U. S. Bur. Entomology

FIG. 320.—THERE IS A RIGHT AND A WRONG TIME TO SPRAY
While the calyx is open (left) the spray may control the codling moth; it is too late when the calyx is closed (right).

These are the general principles for the control of any organism, be it an insect, a mouse, a ground-squirrel, a wolf, a weed, a mold, or a decay or disease organism that is threatening our prosperity. Beyond these principles many details must be learned as to the control of any particular pest.

Should you meet with a creature that appears too abundant, send a specimen to your County Agent, to an expert at your State Agricultural Experiment Station, or to someone at your State University or in the U. S. Department of Agriculture. If it is an old enemy, those experts will be glad to tell, as far as is known, how you may control it. If it is a new pest, they will want to study it. It is no trivial business, this fighting of plant and animal pests, and we still have much to learn about it!

SUMMARY

1. After an epidemic is started, we must find ways of fighting it. Such means will usually be temporary in their effects unless we can re-establish ecologically balanced conditions.
2. Artificial controls are the ways by which man may use his hands or tools to attack the pests. We may attack the pest directly (by hand-picking, weeding, weed-cutting, traps, fly-paper, fire, etc.). We may use poisons to injure the tissue of the pest, stomach poisons (lead arsenate, etc.) against biting insects, or contact poisons (lime-sulphur, oil emulsions, nicotine) against sucking insects. Repellants (paradichlorobenzene, etc.) may keep the pests away before they have attached. Fumigants may be used in enclosed areas.
3. Cultural controls include the growing of healthy crops which will come through less severe attacks of pests. The season of planting of the crops may be regulated so they will not be in a vulnerable stage during the season of activity of the pest. The rotation and diversification of crops will prevent the pest from finding too abundant a supply of any one food.
4. The complete extermination of pests that are general feeders, rapid multipliers, or widely distributed species is probably not to be expected. The extermination of species that are limited in their distribution, confined to a single food plant or to a particular sort of environment, may be more nearly possible. Some of the larger birds and mammals have been exterminated by man. Yellow fever and malarial mosquitoes, and yellow fever and malaria, are exterminated from parts of the Americas. Smallpox is practically non-existent in certain European countries. The Mediterranean fruit fly was exterminated in Florida in 1929 and 1930.
5. Biologic control is an attempt to restore an ecologic balance, usually by the introduction of parasites, predators, or disease organisms that attack the pest in the country in which it originated. Nearly fifty years ago a scale insect pest of orange trees in California was controlled by the introduction of a lady beetle. For many years attempts to use

biologic control against other pests failed. Within recent years government entomologists have learned how to breed and ship the tiny parasites, and many successes are now coming.

6. Native vertebrate enemies of pests (especially fish for controlling insects that live in streams, and birds that are insect- and weed-feeders), may be protected. They will do much to restore ecologically balanced conditions.

7. Wherever a special pest is causing trouble, information on fighting it may be obtained from the County Agent, from the State Agricultural Experiment Station, from the State University, or from the U. S. Department of Agriculture.

DEFINE

Artificial control
Direct attack
Hand picking
Stomach poison
Contact poison
Repellant
Fumigant
Cultural control
Biologic control
Natural control

PROBLEMS

1. What ways do you know of controlling house flies? What are the advantages and disadvantages of each method?
2. What two or three ways do you know of ridding a lawn of dandelions?
3. Which of the plant and animal pests of your community should be controlled by traps? fumigants? hand-picking? cultural controls?
4. Name a number of insects which could be controlled with lead arsenate.
5. Name a number of insects which could be controlled with contact poisons.
6. Which of the local pests cannot be controlled by the efforts of each citizen working independently, but can be controlled by the coöperation of your whole community?
7. Which of the pests in your state need state or federal government help to control? What are those governments doing to control those pests in your state?
8. Name the men in your community who could give you reliable information as to how to fight some pest that was bothering you.
9. How would you address a letter asking your state authorities for help in the control of some one of your local pests?
10. Find out something (from state and federal government bulletins, volumes on entomology, etc.) about biologic controls which may have been introduced into your state to control some of your native pests.

CHAPTER XXXII

FOREST ECOLOGY AND CONSERVATION

Trees are beautiful things!

And a forest is beyond description! Stretches of country, mountain and vale, thick-set with trees! With tall trees and spreading trees, with trees verdant in youth, with trees that are older than a man's memory! With green trees! Beneath them are dark aisles, dank beds of moss, ferns, and fragile flowers. The forest stream, clear, tumbling, and cold, is the nicest of all streams. There live the game trout that delight the fisherman, there the marten and the beaver, the deer and the bear, are at home. The woodland rings with the songs of birds. On the forest floor the camper finds the softest of beds.

So, some day, sooner or later, you must see a forest. You'd like it, I think. You will enjoy it more if you understand something of its ecologic importance.

Soil Factories

Look first at the soil in the forest. It is black. Take it and feel it. It is moist, and it is spongy. It is made in part from the leaves of the trees, from the quantities and quantities of them that decay year after year. No wonder that woods soil grows things in perfection. It contains rich food for plants.

Do you remember how the soil looks out in the old field? Field soil is drier and browner, and often there is only a thin layer of it on top of the still poorer soil that lies beneath. In many forests you would have to dig deep to get through the black soil.

Most soil comes from rocks that get broken. That is mineral soil, but few things grow so well in it as in soils that have an abundance of decayed vegetable matter. All plants contribute to the making of vegetable soil, but because of their size trees are the most important plants in this respect. The soil of many of the best farmlands of the country originated in forests.

Photo by E. S. Shipp
Courtesy U. S. Forest Service

FIG. 321.—TREES AND A FOREST

Climate Regulators

Forests have a distinct effect on the climate of a region.

Temperature Regulators.—Look up through the forest. It is dense, and it is shady. The heat of the summer sun is kept out; the cooling moisture of the soil is protected; the chill dews of night will not enter; the winter winds will pass over. Here beneath the shelter of trees the old camper bunks for the night, and he knows a warmer bed than the tenderfoot who sleeps in the open. Forest temperatures are a few degrees more even than those of the open.

In addition to the coolness due to the shade, the temperature of the summer forest may be lowered by the evaporation of water from the leaves of the trees. A hundred gallons or more of water may pass from a big oak tree in a day. A hundred gallons of water taken up through the roots, up through the trunk, and out through the stomata of the leaves! All evaporation is accompanied by a cooling process. A wet bathing suit feels uncomfortably cold because of the water evaporating from it. No wonder the air of the forest is more moist and cool than that of the open.

Air Purifiers.—Not just air, but pure air, belongs to the forest. You already know how green plants in their work of food manufacture take in carbon dioxide and give out pure oxygen, the gas so necessary to both plants and animals for respiration. Forest trees are, of course, the most important because they are the largest and most abundant of plants. Each year an average leaf takes in as much carbon dioxide as there is in a column of air two and a half miles high and as large across as the surface of the leaf. Each year it releases as much oxygen as there is in a similar column of air 18.5 feet high. Each of the leaves you are looking at may do that!

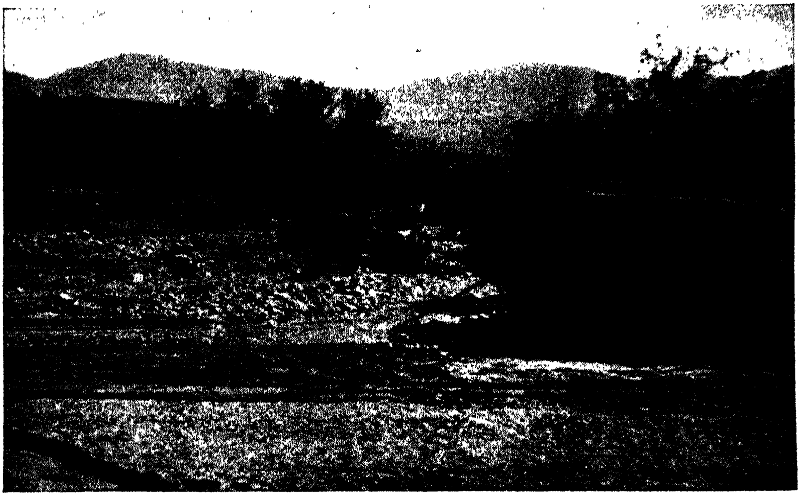
Windbreaks.—But look again into the forest. The tree tops are tossing, and the wind is singing through them. Each tossed branch helps break the effect of the storm. As windbreaks, trees are very important. The eastern United States hardly realizes this, for it has always had forests, but the prairie and plateau settlers soon learned that their homes needed trees planted about them. In Southern California tall-growing trees, often eucalyptus, are planted about the orange groves to keep off the cold winds from the mountains, and the hot and dry winds of the more desert areas.

Which reminds me:—That a good camper knows how to get through a storm in a forest without getting wet. But once a certain party tried the same methods in a place that was without trees, and the storms descended, and the winds blew, and their shelter wouldn't work, and they shivered in wetness, and ate a cold breakfast—and loved trees ever after!

Soil Conservation

Now look at that hillside. Steep as it is, it still holds together. See the trees that grow on it. Their roots are holding the soil, preventing landslides. Grass roots are important soil-binders, and grass is sometimes planted to protect railroad embankments. Perhaps you have grass holding up the terrace about your own home. On high and steep slopes, tree roots are necessary.

Do you remember the old cut made by the road near your house? You recall how bare it is, and how much debris accumulates at its base because the bank is continually going to pieces, and that sometimes they have to shovel to keep the road clean. In the same way, hillsides wash away if they don't have trees on them.



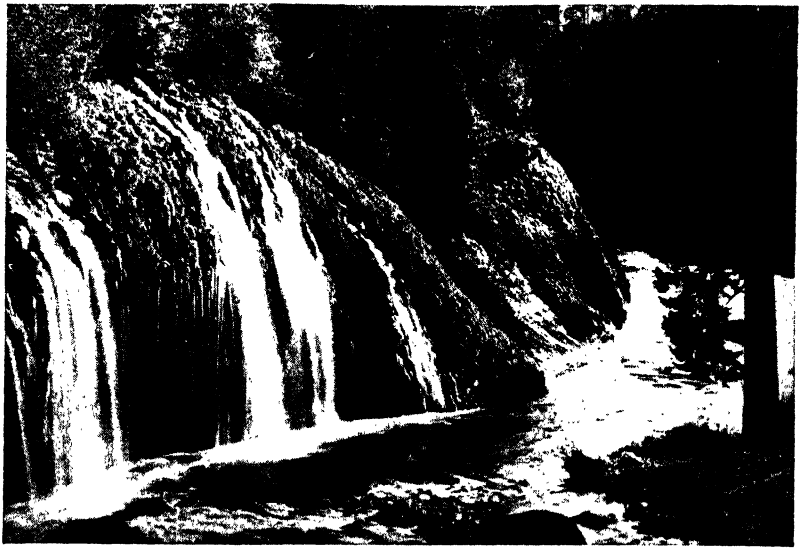
Courtesy Ancil Holloway

FIG. 322.—VEGETATION HOLDS THE SOIL

In northern Arizona. The bad wash develops where there is no vegetation.

No hill or mountain country can prosper after the forests have been removed. In some of our mountain regions, the forests have been stripped from the hillsides, leaving them desolate and unprofitable places. With the soil gone, the slopes cannot be reforested without years of labor. Even though lumber has a very great commercial value, the slopes of every hill and mountain should have enough trees left growing to hold the soil upon them.

Once I met a man who said that his home had been high in the mountains of the Austrian Tyrol, and that there the spring rains washed the soil off the upland farms because too many trees had been cut from them, and that each spring the mountain folks had to go down into the valleys to buy back their soil and put it in bags on their donkeys and carry it back into the mountains!

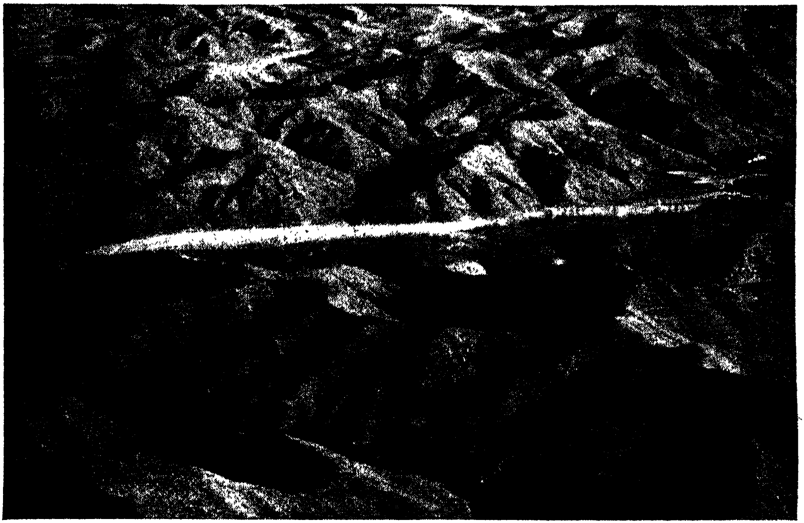


Courtesy U. S. Forest Service

FIG. 323.—THE DEPENDABILITY OF THE FOREST STREAM
Forest country is moist country because it regulates the rate of run-off of the surface waters. View in western Oregon.

Stream Controls

But forests are of still greater importance in connection with the moisture they store. The forest floor is loose and spongy with decaying stuff, and it soaks up the rains as they fall on it. This moisture is let out into the brooks only gradually, and consequently forest streams do not know such floods or droughts as the streams of the open places. The dependability of forest streams makes them the necessary source of much of our permanent water supply. Parts of our Southwest are absolutely dependent for drinking water and for irrigation upon forests which are located in the mountains. Western deserts have become fruitful places, the Southern California desert has become part of the land of roses and orange blossoms, chiefly as the result of irrigation made possible by the streams of the forested mountains.



Courtesy Bailey Willis and Carnegie Institution

FIG. 324.—DEFORESTATION IN NORTHERN CHINA
Note the town at the extreme right.

The rains that fall onto a bare land immediately run off into swollen water courses, and they do much damage. Many floods which destroy crops, lands, homes, and lives are due in considerable measure to deforestation at some stream's headwaters. There are few years when the Middle West does not have such calamities. The great levees of the lower Mississippi Valley are testimonies of the danger.

The same streams that have been floods become in a few weeks abnormally shallow, for the water supply was exhausted in the time of high waters. The smaller streams of the open become small trickles or baked or dusty arroyos in a land of drought. Both floods and droughts may be the result of the one thing, deforestation.

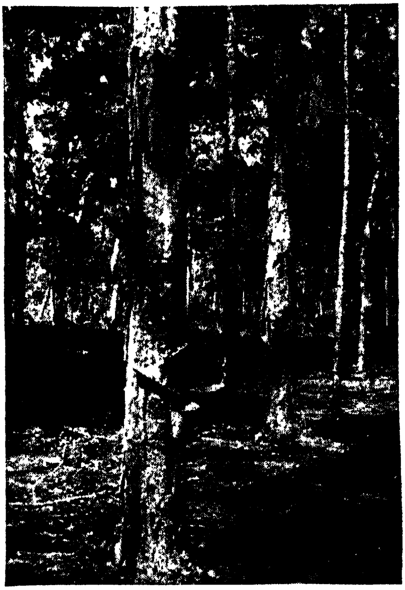
Courtesy U. S. Forest Service

FIG. 325.—A LUMBER MILL, LOUISIANA

One of the best, or worst, examples of the effects of deforestation is to be found in China. The northern parts of that country were once forested. Now they are desolately barren, with the result that floods periodically destroy crops and homes and many thousands of lives. Droughts and famines take a heavier toll. The poverty-stricken, poorly nourished people are unable to withstand diseases, and epidemics sweep away millions of them. It is not surprising that the nation has not found time or resources to develop the finer things of our modern civilization.

Commercial Values

The commercial values of our forests are more often appreciated than the more generally ecologic values which we have just considered. Forest trees are the source of the lumber which we use in building houses, ships, furniture, boxes in which to ship goods of all kinds, railroad ties, and many of the tools and utensils in daily use. While brick, steel, and concrete are more and more entering into the construction of even private dwellings, perhaps 75 per cent of all the homes in this country are still made entirely of wood. Few other things enter into our everyday lives so directly as the products of our forests.



Courtesy Prof. P. Weatherwax, Ind. Univ.

FIG. 326.—PINE TREES ARE THE SOURCE OF TURPENTINE

The sap which oozes from the wounds in the bark is collected in buckets, and the turpentine is obtained by distillation of the sap. Photo made in Florida.

While coal and oils and gas have done much to replace wood as a **fuel**, nearly a half of the wood taken from our forests is still used for burning. In the nation as a whole, we are more dependent than is generally realized upon this source of fuel.

Most **paper** is made from wood worked into pulp. The publication of books, periodicals, newspapers, and other paper products is largely dependent upon our ability to find sufficient materials in the forests of North America.

Numerous by-products of the forest add much to their commercial importance. **Turpentine**, much of the **wood**

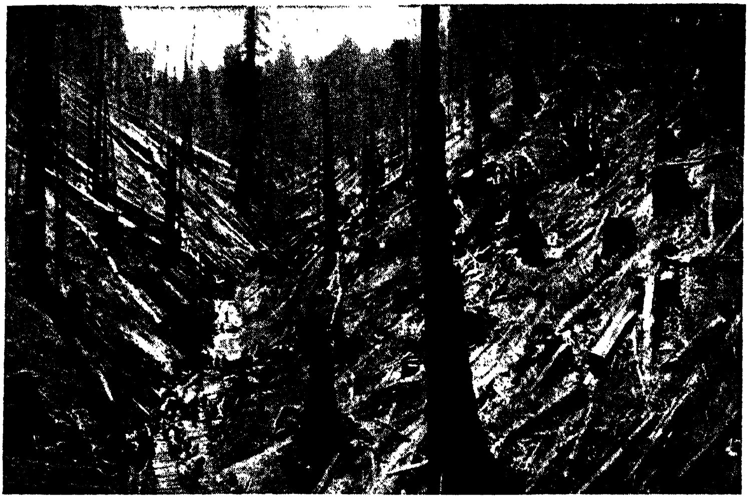


Photo by C. S. Crandall. Courtesy U. S. Forest Service

FIG. 327.—ONE WAY OF LUMBERING

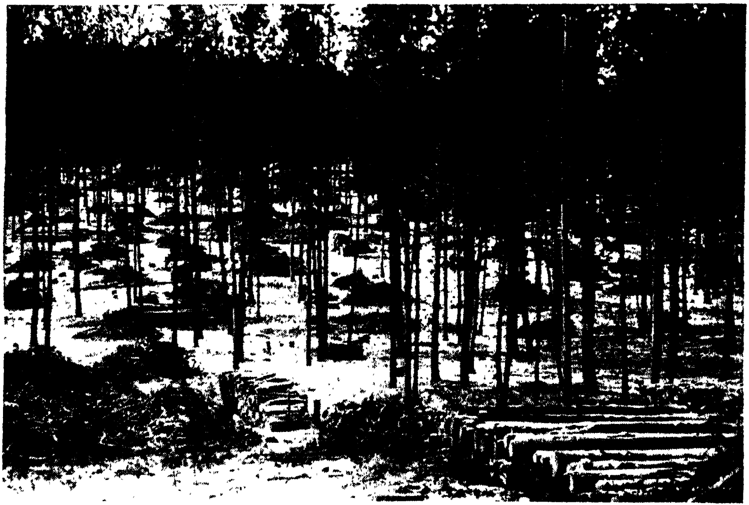


Photo by C. S. Crandall. Courtesy U. S. Forest Service

FIG. 328.—ANOTHER WAY OF DOING IT

Stumps cut low to save timber, brush piled for safe burning, young trees left for future growth.

alcohol of commerce, **tars, resin, balsams, gums,** various **oils, acetic acid,** and other such materials are derived from forest trees. The **tannin** used in preparing leather is a product of the bark of hemlock and of some other trees. Maple **syrup** and **sugar** provide an important revenue in certain parts of the country. **Charcoal** is a prepared wood fuel. A **cattle feed** is being made from sawdust. More than a third of all the **silk** now used in clothing is made from wood fiber rather than from threads woven by silkworms.

A Wood Shortage.—And yet with all our economic dependence upon our forests, we are facing a wood shortage that will become severe if we do not take steps to prevent it. We are using four times as much wood as our forests annually grow. In the past we have been able to do this because we could reap the crop that grew before the white man's invasion. The major part of our virgin forest is, however, now gone. Such a state as Michigan, once believed to contain "inexhaustible" stands of timber, is now so depleted that it has to pay millions of dollars each year to import lumber from Oregon, Louisiana, and other points more or less distant.

Even if forests were of no importance as soil-binders and stream controls, the economic problem is so pressing that we should have to consider how to guarantee sufficient wood for our own use and for the use of the generations to come.

Forest Conservation

Fortunately, the solution of the forestry problem is known, and as a nation we are beginning to work toward it.

Improved Management.—Only one-third of the wood that is taken from our forests is ever used. The rest is wasted by extravagant methods of lumbering, milling, and manufacturing. With an easy improvement in methods it would be possible to save another third of the crop, and that would double the commercial value of our forests without using any more trees than we now cut.

For the rest of the increase in our forest crop we must look to better management of the forests. We can grow forests on lands, chiefly mountain countries, that are of little value for anything else. We can so help forests to grow that we can reap all of the wood necessary for commercial uses, and still preserve enough growing trees to function as soil-binders and stream controls, and to guarantee the future lumber supply.

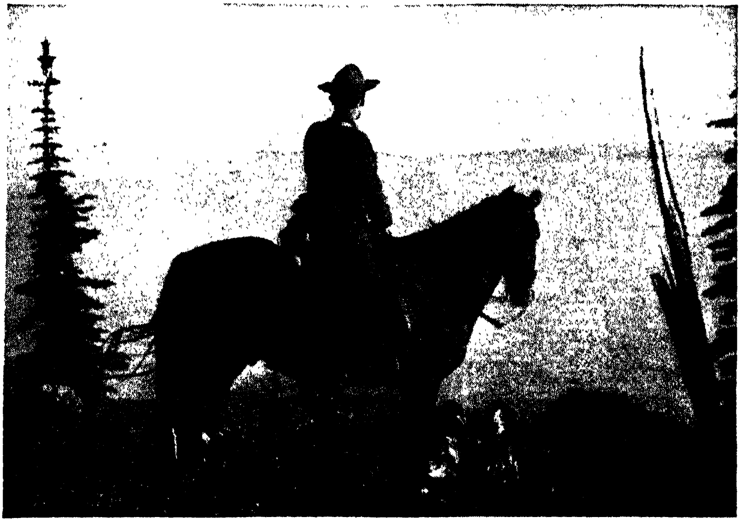


Photo by W. J. Lubken. Courtesy U. S. Forest Service

FIG. 329.—THE FOREST RANGER

It is only necessary that the cutting of a forest be limited to a part of its trees, that the younger trees be left and protected from the falling timber, that the younger trees be protected from grazing sheep and cattle, and that fire, the worst of all forest enemies, be prevented. New trees must be planted in deforested countries, and growing trees must be protected from insect enemies and fungus diseases. A forest so grown, maintained, and utilized may become a good business investment. Such investments are our National Forests, managed by the Forest Service, one of the most picturesque branches of our government.

National Forests.—These National Forests furnish some of the finest scenery in the country. When you travel afar to see our land, be sure to go to the National Parks and to the National Forests. Probably nothing will make you prouder of America! While most of us, private citizens, may never engage in forest growing, by supporting the work of these National Forests we may do much to help the situation in this country.

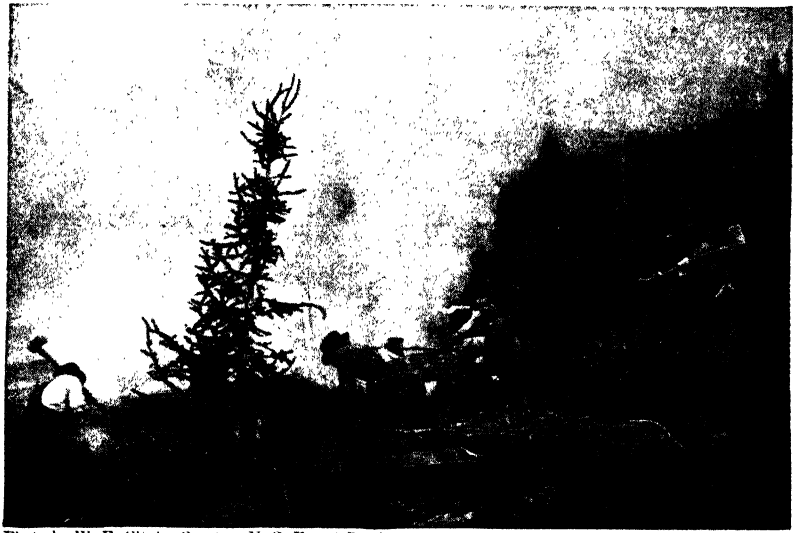
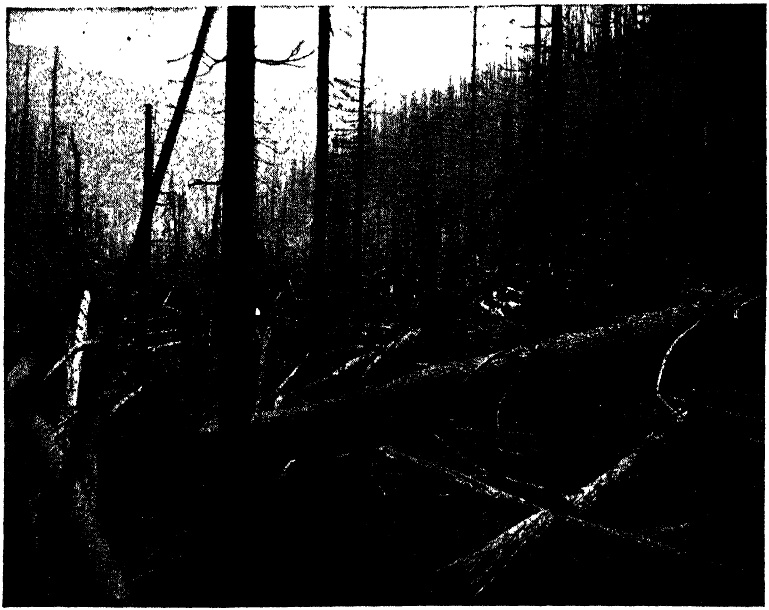


Photo by W. F. Clinie. Courtesy U. S. Forest Service

FIG. 330.—FIGHTING FOREST FIRE

Fire Control.—One of the most difficult of forestry problems is the protection of a forest from fire. Scanning the country from some mountain lookout, the ranger sees a wisp of smoke away off in the forested area. Telephone lines carry the word to the fire chief, and from the reports of several stations the blaze is located. Rangers are assembled and rushed to the spot as fast as forest roads and trails will allow; but often it is difficult to get forces together in time to prevent the ruin of thousands of acres of timber and country.

Have you ever seen a forest fire? It is terrifying to behold. I have seen blazes start in pine country, and in a moment they had spread as fast as the winds could carry them. Once, in Oregon, a cigarette started a fire only 350 yards away from a ranger. Within half an hour a hundred men had been assembled to fight it, and another fifty were there in another quarter of an hour. But it took forty hours of terrific work to put the fire out. Some forest fires will burn for many days or even whole weeks.



Courtesy U. S. Forest Service

FIG. 331.—AFTER WIND AND FIRE, IDAHO

There are over 36,000 fires each year in the forests of this country. Some of them are started by lightning, and they are

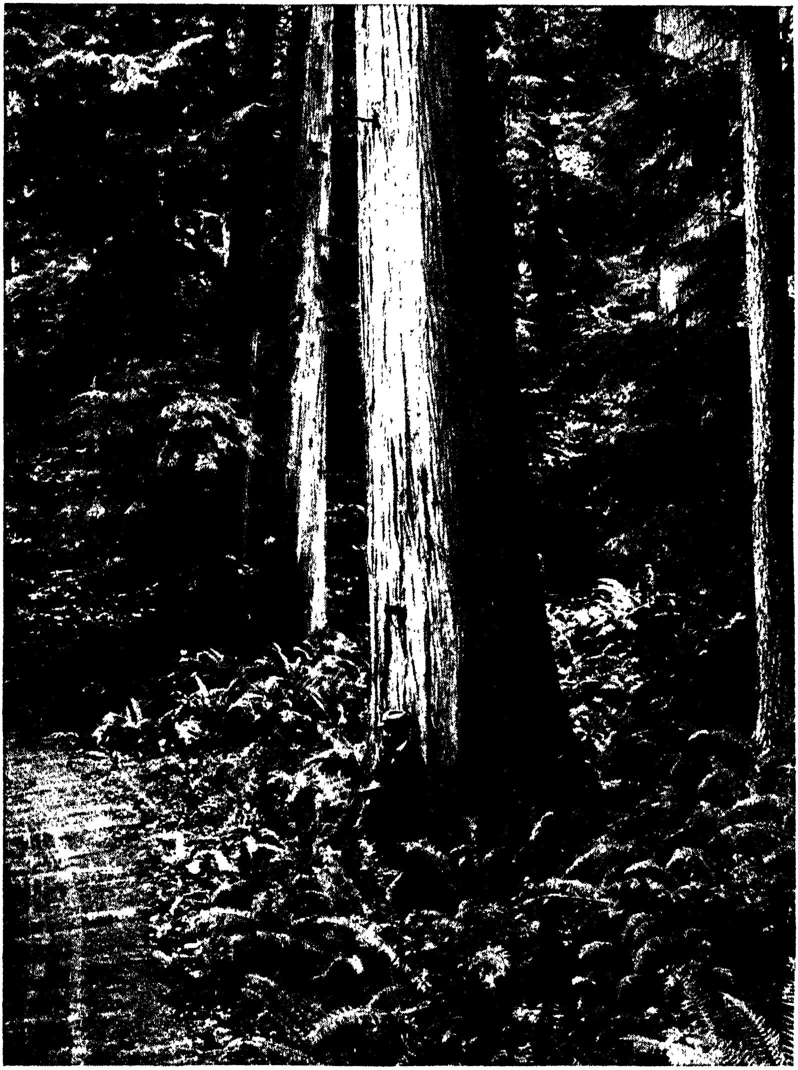


Photo by A. Gaskill. Courtesy U. S. Forest Service

FIG. 332.—THE GREEN FOREST
Washington State.

not preventable. Sixty per cent of the forest fires whose causes are known are due to human agencies. Most of these could be controlled. Many of the fires are started by careless campers and by railroads. Here is one point at which the average citizen may actively help. When you go into the woods, BE CAREFUL WITH FIRE. The Forest Service warns you that *no fire is out until the last spark is extinguished.*

Many severe forest fires, nearly a third of all the fires in certain parts of the South and of the far West, are started deliberately by people who want to see the forests destroyed, believing wrongly that by so doing they will provide more grass for their sheep and cattle, or room to grow crops. So little do many of our citizens realize that their ranches and farms may not be able to survive if the forests are not adequately maintained.

I wish you might see some burned-over country! It would inspire you with deep thought. Blackened earth, bared rock, dried streams, charred sticks; an awful stillness broken neither by brook nor singing boughs nor bird nor beast; a desolation that was easy—so easy to start, but so difficult to repair! I have seen the charred stumps of New England spruces, of cedar in the Rockies, of oak and hickory in the Southland, and of three-century-old sugar-pines in the California mountains. Everywhere they presented the same picture of desolation. I much prefer the green forests!

SUMMARY

1. A green forest is one of the most beautiful things in the world about us.
2. The floor of the forest is rich with the vegetable soil derived from the decay of the forest leaves. Soil in the open is largely mineral soil derived from broken rocks, unless vegetable soil has been carried to the field from some forested region.
3. Forests protect the air from too rapid changes of temperature. In the summer they lower the temperature by evaporating great quantities of water through their leaves.

4. Forests purify the air by taking in carbon dioxide and giving out oxygen during the process of photosynthesis.

5. As windbreaks forests are indispensable.

6. The roots of forest trees hold the soil on steep slopes, preventing landslides. The protection of the forest roof prevents soil erosion. With the removal of the forest a region may soon become so badly eroded as to be unfit for human habitation.

7. The forest floor absorbs the water from rains, and lets it out only gradually into the streams. Regions without forests are liable to floods following storms. Droughts follow because the floods have carried away the available waters too quickly. One of the greatest values of forests is in their service as stream controls.

8. Commercially, forests provide lumber for furniture, implements, and houses; fuel; paper; turpentine, alcohol, tars, tannin, artificial silk, [illegible], etc.

9. We face a lumber shortage, for we are annually using four times as much wood as we grow.

10. Proper methods of lumbering would double the production of forest products without using more trees than we now cut. Reforestation and better management of our forests will provide the rest of the timber we need. National and state forests are designed to increase our supply of forest products, as well as to preserve the forests for their ecologic uses.

11. Fire protection is the most serious problem in preserving a forest. By being careful of fire when we are out-of-doors, each of us may contribute to the preservation of the green forest.

DEFINE

Mineral soil
Vegetable soil
Deforestation
Forestry
Erosion

PROBLEMS

1. Describe the processes through which bare rock may become covered with soil.

2. Is a gentle shower or a beating rain better for plants? Explain.

3. Explain why the color of soil may be used as an indicator of its richness.

4. Why is the soil of lowlands usually darker in color than the neighboring hillsides?

5. Such "cover crops" as rye are planted in the late summer or early fall. Why?

6. How does the planting of grass on sand dunes stop the drifting of sand?

7. As a soil-binder, which would be better, a crop of grass or a crop of turnips? Explain.

8. Explain why a well-forested region suffers less from drought than one with no forests.

9. In just how many ways have you, personally, ever used wood or other forest products? List them.

10. Is there more or less forest in your state than there was fifty years ago? What has caused the change?

11. What is being done about forestry in your state? Are there public-owned forests in your state? Where are they? Who is your State Forester?

12. Do you know any of your state laws affecting forests?

13. Where are the chief forests that control the water supply (reservoir, irrigation, and streams) in your county and state?

14. What eight states still have the largest forested areas?

15. Why are the National Forests mostly in the Far West? Would State and National Forests be as important in the East?

16. In how many ways do you ever expect to be able to help in forestry? Explain.

17. Rich woods soil is good soil in which to grow most kinds of plants. In what ways does such soil aid the plant in its growth?

18. Where did the soil in your particular region come from? Follow its history in as much detail as possible.

19. Make a list of all the phyla and classes of plants and animals which contain important enemies of forests.

20. List mammals which do damage to forests, and tell how each does the damage.

21. Have you ever seen a forest fire? or had an account of one from someone who actually saw it? Tell about it.

22. Have you ever seen a flood? or had an account of one from someone who actually saw it? Tell about it.

23. Were there floods in any of our larger river valleys before white man arrived? Carefully gather your evidence.

24. How many ways does man have for controlling floods in our large rivers? Which are the best?

25. Compare the advantages and disadvantages of a forested and non-forested country for human habitation.

CHAPTER XXXIII

INSECTS

Look about you. Which of all the plant and animal groups appears to be the most important and the ecologically dominant one in the balance of nature?

Trees.—Would you say the trees? They are large, and occupy much space, and they are certainly important. But trees do not occur everywhere, for they are not to be found in water, on mountain tops, or on the great plains and deserts which constitute so large a part of the western half of our country. And trees are ready victims of insect and fungus attacks. No, they are not the dominant organisms.

Green plants in general are abundant, and they are indispensable as the ultimate sources of foods for animals. But few green plants are able to withstand the attacks of insects, and they cannot be said to be the dominant organisms.

Birds, as we shall see later, are regulators of balanced conditions, but their importance depends upon the importance of the insects and weeds that they destroy.

Man, of course, thinks himself very important. Certainly he has been able to work great damage upon the rest of the living world. But he is still the easy victim of microscopic disease organisms, and he still meets defeat in most of his engagements with the insect world.

Insects, insects, insects, triumphing every time over these other groups! It is apparently correct to say that the insects are the dominant organisms. Five-sixths or more of all the known species of animals are insects. Insects abound practically everywhere (with the exception of the salt seas); forests and prairies, swamp lands and deserts, mountains and lowlands are all the abodes of the tiny giants. No plant is safe from their attacks; no higher animal but has its insect pests and parasites. The Arctics and the tropics of every continent are so much the possessions of the insects that man has been able to do little toward settling those regions. Man divides his foods perforce with the insects. Disease organisms distributed by insects may and often do claim human lives. Man is still secondary to the insect. The greatest ecologic problem that we face today is to learn enough about insects to control them.

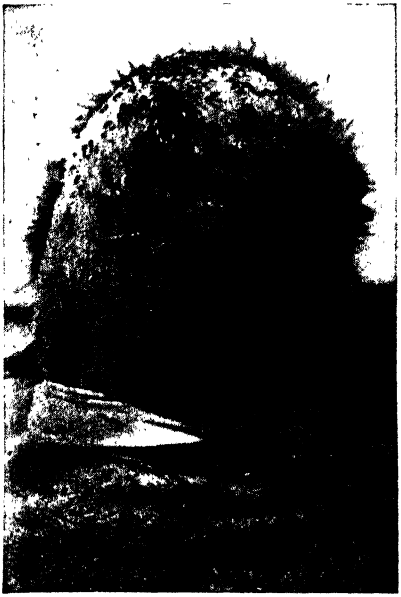
Reasons for Dominance

Small Size.—This is the insect's greatest asset. Most insects are as small as or smaller than an ant. Small shelters suffice to protect them from unfavorable weather conditions. Like the proverbial flea they easily escape the attacks of other animals. Often they are not even noticed in their tiny hiding places. Small amounts of food will maintain them.

Short Life Cycle.—Most insects live for perhaps one year. Some plant lice complete the cycle within two weeks, and for the common house fly under very favorable conditions the cycle may be completed in eight days. An animal with such a short cycle does not have to provide a house, a coal-pile, woolen clothing, or other such means of getting through the unfavorable conditions of winter, for it may exist as an inactive egg or pupa at that season.

Rapid Reproduction.—The short life cycle of the insect increases its rate of reproduction. Man's life cycle averages over twenty years (from birth to birth) and that puts him at a considerable disadvantage with lowlier organisms. The rapid rate of insect reproduction is also due to the many eggs they may lay. Perhaps 100 is the average, but 6,000 is not an unknown number with some species. The descendants of a single pair of house flies might number 5,600,000,000 at the end of a year if every individual survived to maturity. Of course, only a small percentage of the number ever does survive, but even then there is no danger of such animals' soon becoming extinct.

Adaptability.—Insects are adaptable organisms, thriving when conditions are ideal, but also managing to get along under adverse conditions. Few corners of the earth are so barren that insects cannot live in them. Some insects live on materials that would not nourish other animals; some species feed on dry wood, several beetles eat feathers and furs, the clothes moth feeds on dyed wool cloth, and the museum beetle feeds upon dried animal remains in museum collections. Many insects survive temperatures below freezing, and some of them are active on the snow. A considerable number of species lay eggs that grow without fertilization. It is not surprising that insects have become the dominant organisms.



Copyright R. M. Anderson
Courtesy Amer. Mus. Nat. Hist.

FIG. 333.—MOSQUITOES ON THE HOOD OF AN ESKIMO
Summer, within the Arctic Circle.

As Direct Pests

The cockroach in the corner, the blood-sucking mosquito, the ant in the pantry, and the fly in the soup make life miserable by their very presence and the personal discomfort they inflict. If we can, we shun places that are ridden with them. At any rate, we avoid mentioning such things, hoping that our lack of recognition may in some way or other reduce the numbers of the pests. Consequently, the pest continues to multiply.

There are many places in the world which man cannot happily inhabit because of the abundance of insect nuisances. This is true of most parts of the tropics, and conditions are bad enough in some sections of our own country.

Arctic Pests.—This is a more serious problem in the Far North, and even the northern parts of our country suffer severely from insects in mid-summer. Two-winged insects, such as flies, gnats, black flies, midges ("no-see-ums"), and mosquitoes are the chief causes of trouble in the North. One who has not been in the northern forests during fly and mosquito seasons can hardly appreciate how intolerable insect pests may become. Lumbermen in that country may wear gloves and mufflers while they work. Arctic explorers tie tight the sleeves and necks of their jackets and wear gloves and head nets against the insect pests. Even pack dogs may have their heads enclosed in nettings for protection. Mosquitoes may be so abundant on the bare back of an Indian as nearly to

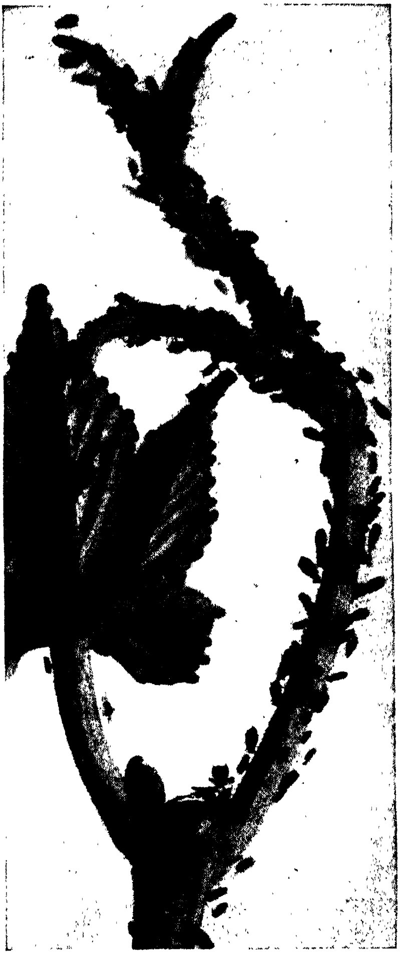
Courtesy U. S. Biol. Survey

FIG. 334.—SCREW WORMS ON THE SKIN OF A REINDEER

hide the color of his skin. The Arctic is unattractive for one reason because of its hordes of insects.

Direct Attack.—Some insects inflict actual wounds on the animals they attack. Bees, wasps, and hornets are not the only insects equipped to cause pain. Some kinds of ants and beetles, and certain water bugs and bedbugs, inflict wounds that are often complicated by poisons injected by the insect, and by bacteria that subsequently enter the broken tissue. Many flies, mosquitoes, horse flies, the midges and black flies already mentioned, and many kinds of lice, ticks, and fleas seriously wound many of the larger mammals besides man.

Less familiar are the insects that take up their abode within the bodies of animals. These insects are mostly larvæ, the adults of which chew out of their hosts and live in the open. Cattle are commonly injured, possibly 75 per cent of them harboring bot flies, screw worms, or warbles at some time during their lives. The larvæ move from tissue to tissue and cause swellings (warbles) be-



Courtesy U. S. Bur. Entomology

FIG. 335.—PLANT LICE ON GRAPEVINE

neath the skin. One kind of bot fly occurs in the heads of sheep, producing the common disease called staggers. Bot fly larvæ are very often present in horses kept in open pastures. The human may fall victim to bot fly larvæ that get into the digestive tract or some of the other body openings. Such occurrences are rare in the United States, but are very common in the tropics.

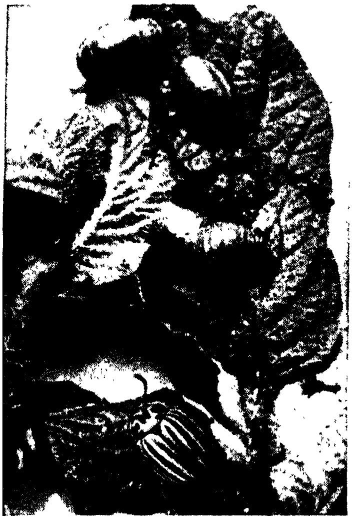

Courtesy U. S. Bur. Entomology

FIG. 336.—COLORADO POTATO BEETLE

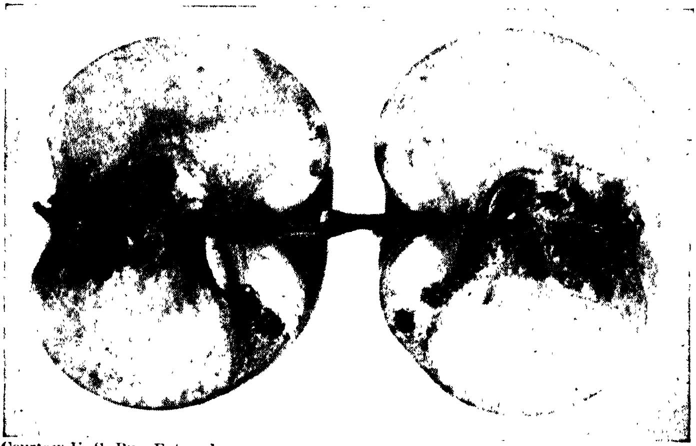
Larvæ (above) and adult (below).

Only the temperate zones of the world have been particularly favorable to human civilization. Until we learn better how to control the insects, man cannot go very far in settling the other parts of the globe.

As Enemies of Agriculture

It is estimated by government experts that one-tenth of all our agricultural crops, foods, fodders, and fibers are destroyed annually by insect pests. That means that over two billion dollars are paid each year as America's share in feeding the insect world. That is a sum beyond human comprehension. It is almost as much as it costs us to run our whole national government, including the army and navy, courts and executives, and all the other things for which congress appropriates money. If we could completely control insects, we might pay our taxes to the federal government with the money saved. In order to contribute to the support of the insects, the farmer today has to work 10 per cent harder than he otherwise would; every man, of whatever occupation, pays ten cents of every dollar spent for his food and his clothing as a war tax to support the armies of the enemy.

Insects attack the roots, the stems, the leaves, the flowers, and the fruits of plants. Hardly a green thing grows that does not have to meet these enemies. Some species chew up the tissues; others suck the saps and juices; others inflict wounds that produce tumors or prevent normal growth. Potato beetles, tent caterpillars, grasshoppers, locusts, the Hessian fly, the chinch bug, gipsy moths, the San José scale, army worms, weevils, plant lice, cabbage worms—some of these names are familiar to every man who has ever attempted to grow crops.

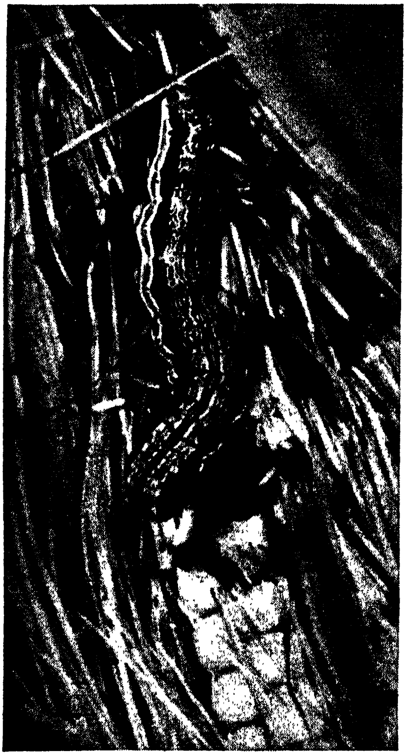


Courtesy U. S. Bur. Entomology

FIG. 337.—CODLING WORM IN APPLE

There are, moreover, hundreds of other crop pests. The codling moth is said to destroy $30,000,000 worth of apples each year. The corn ear worm, damaging chiefly the tips of the ears of corn, is estimated to work $100,000,000 damage on that crop annually. The cotton boll weevil destroys over $160,000,000 worth of cotton in a year. This insect is one of the most serious obstacles to the prosperity of our Southland, and is in no small degree responsible for the price of cotton clothing. These are among the worst, but they are only a few of our many insect problems.

After the crop is harvested, it is still not safe. Insects ruin the stored materials of corncribs; they flourish in granaries and mills; they spoil a goodly part of the grocer's stock, and they invade the pantries in our homes. Small, as usual, most of these pests escape notice. Nevertheless, it is safe to say that there are very few pantries, even in the finest homes, that do not harbor pantry beetles, grain moths, grain weevils, or grain beetles at some season each year.

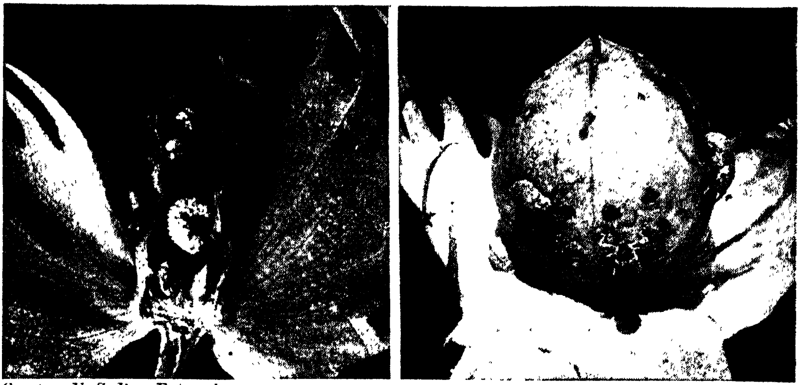


Courtesy U. S. Bur. Entomology

FIG. 338.—THE CORN EAR WORM

Damaging the silks and young kernels of corn.

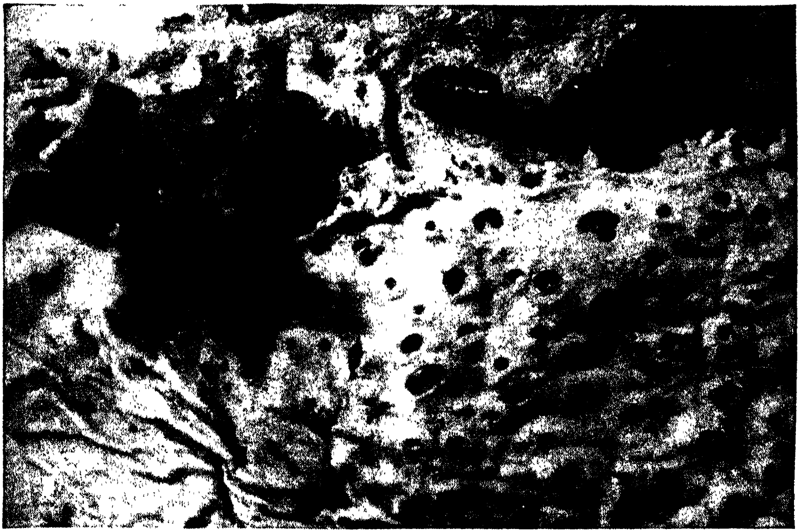
In Animal Industry.—Our animal crops, horses, cattle, sheep, hogs, chickens, also fall prey to insects. The annual loss in the animal industries amounts to $100,000,000. The warbles and screw worms seriously bother or kill cattle and then ruin their hides for use as leather. Cattle ticks (related to spiders) seriously injure stock in parts of the country and spread the disease organism of Texas fever. Many kinds of sucking and biting lice bother and seriously injure the animals of our farms and ranges. Constant irritation by such tiny pests may so interfere with the larger creature's metabolism that death results. In an earlier chapter we have pointed out that these insect pests are often the means by which the germs of diseases of stock animals, as well as of man, are distributed.



Courtesy U. S. Bur. Entomology

FIG. 339.—THE COTTON BOLL WEEVIL

Larva in "square," and adults on boll.



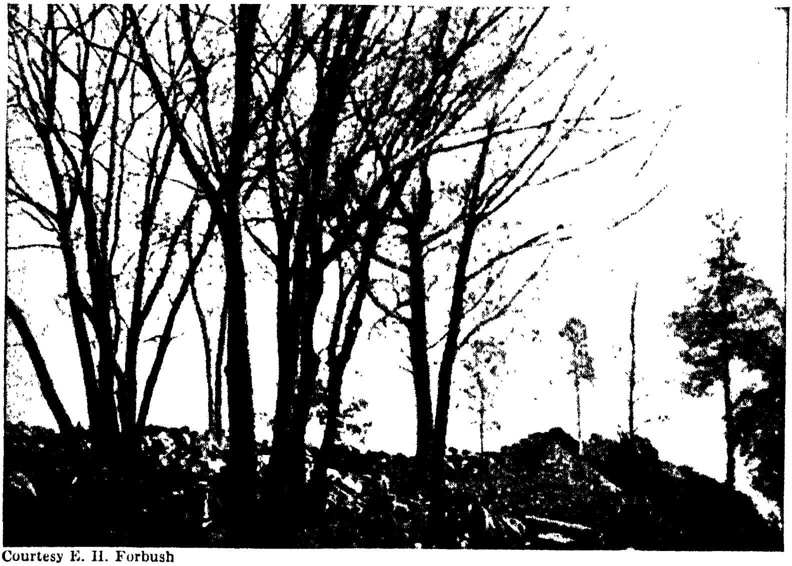
Courtesy U. S. Bur. Entomology

FIG. 340.—BOT FLY LARVÆ IN HORSE'S STOMACH

Showing damage done to the walls of the stomach.

As Enemies of Forest Conservation

The commercial values of our forests and shade trees are reduced about $150,000,000 a year by the ravages of insects. To this must be added the damaging results of deforestation, the effects of which are probably considerable, although they cannot be accurately reckoned.



Courtesy E. H. Forbush

FIG. 341.—TREES IN JULY STRIPPED BY GIPSY MOTH CATERPILLARS—MASSACHUSETTS

Forest insects may feed upon the leaves of a tree, in which case the plant is unable to manufacture food, and it starves to death if it is stripped two or three times in succession. Some leaf-feeders strip woodlands as bare of leaves as though a forest fire had swept the region. Many insects live directly beneath the bark, feeding upon the growing cambium of the tree. When such insects chew completely around the trunk the girdling, of course, kills the tree. Other forest insects destroy the more solid wood of trees, allowing them to be blown over in storms.

Few insects will penetrate solid bark. Don't provide entrances for the pests by whittling or hacking at trees. Don't break off branches; but cut them smoothly, close to the main stem, and then bark will grow over the wound, much as it would have grown had the branch died naturally. Put shellac on the cut cambium immediately (within three or four minutes) after its exposure, and later paint the whole wound with coal tar or with a lead paint to help discourage insects and fungus invaders.

As Disease Carriers

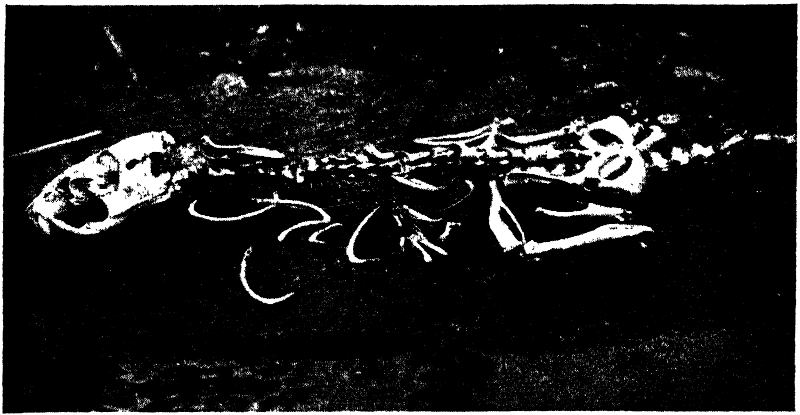
The money losses from disease cannot be reckoned. It is difficult to measure the cost of lost time and suffering during illness, and no one can tell the value of human lives. Insects, as we have seen, carry about organisms that cause disease and death, thereby becoming responsible for a goodly share of our misfortunes. Review what we learned on this subject in the chapter on Carriers of Disease.

Beneficial Insects

It is unfortunate that we recognize enemies more often than friends. After considering the ways in which some insects work damage to our health and wealth, we should realize that other insects prove their dominance by serving man in definitely beneficial ways.

Pollinators.—As pollinators, carrying pollen from the stamens to the pistils of flowers, insects are more important than any other animals. Some of our food, fruit, and forage crops are thus dependent upon insects, and many of our more conspicuously colored wild flowers could not exist without the moths, bees, or wasps. What a dull world this would be without flowers to color it!

Scavengers.—Also directly economic is the scavenger service which many an insect performs. Insects are only one of the scavenger agencies, but they are very effective. A dead rabbit placed in a field in the summer soon becomes a moving mass of thousands of maggots, the larvæ of flies of several species, and within four or five days nothing but clean bones will be left of the mammal. As large an animal as a bulldog may be completely covered with earth within a week's time by the activities of a dozen burying beetles. What is more familiar, the manure of country roads and pastures does not accumulate as might be expected because dung beetles, some of them rolling those interesting balls of dung down the road, some of them throwing earth over the manure and working from underneath the pile—dung beetles dig the material underground where they feed on it at their leisure.



Courtesy P. G. Howes, from Insect Behavior, Badger Publ.

FIG. 342.—BLOW FLY LARVÆ CLEANED THIS MUSKRAT SKELETON

Once, on a dusty road in Arkansas, I sat through half of a lazily hot day and watched the dung beetles cleaning the refuse that a large herd of cows had left in the morning. Within five or six hours no bit of exposed dung was to be seen on the road. When finally I passed along, I had gained a considerable respect for that portion of the insect world.

Predators and Parasites.—The insects that feed upon other insects, acting as predators or as parasites on or within the bodies of their hosts, are, as we have already discovered, effective means of maintaining balanced conditions in nature. Perhaps you have seen caterpillars, tomato worms for instance, bearing a dozen or more tiny whitish cocoons protruding from their bodies. They were the cocoons of parasitic insects, and those caterpillars never matured to lay their eggs. Sometimes among all the caterpillars on a badly infested tree it is difficult to find a single individual that is not affected by insect parasites. Most of the beneficial parasites are tiny, wasp-like forms that live during their larval stages in the eggs or in the larvæ of other insects. Some of the species of two-winged flies are also parasitic in their larval stages.

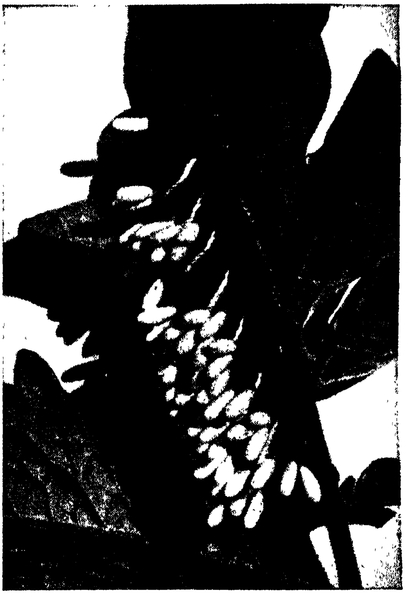
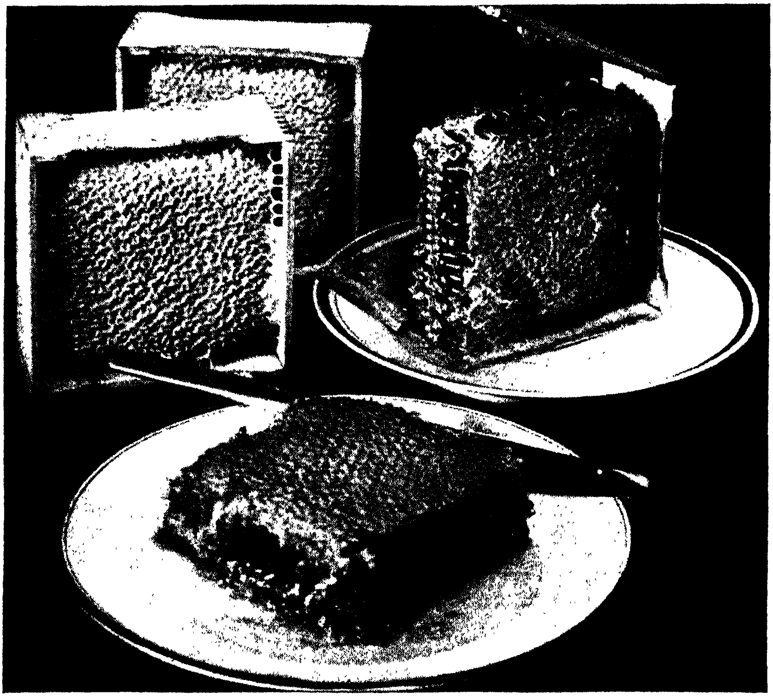


Photo by M. C. Dickerson
Courtesy Amer. Mus. Nat. Hist.

FIG. 343.—A TOMATO WORM WITH COCOONS OF A PARASITIC WASP

The predatory insects are usually larger, as they must be in order to chase and capture their prey. Wasps, bees, and ants are often predatory; many kinds of bugs, especially water bugs, are also predatory. Some of the larger, out-of-door kinds of flies, and some of the beetles are among the most beneficial of predaceous insects. The slender, mostly black, ground beetles found beneath boards or under stones are beneficial as predators, and one of the more brilliantly colored species of ground beetles was imported into New England to help fight the gipsy moth (see Fig. 315). Practically all of the lady beetles (ladybugs or ladybirds) are beneficial as predators in their larval stages. Such insects should become known to you and should be protected.

Weed Destroyers.—We may even consider as beneficial some of the insects that feed upon plants, for they may thus destroy obnoxious weeds.



Courtesy U. S. Bur. Entomology

FIG. 344.—A CROP WORTH $75,000,000 ANNUALLY

Commercial Value.—There are a few insects that produce materials useful to man. The honeybee annually furnishes the United States with about $75,000,000 worth of honey and beeswax. The cochineal insect, a native of Mexico, is one of the several scale insects that furnish valuable dyes. The caterpillar of an Asiatic moth is practically the only source of the true silk with which we make thread and cloth.

As Objects of Interest.—Finally, as creatures whose structures are remarkable, whose ways are curiously different from those of the human, whose performances are complicated and successful out of all proportion to the tiny nervous systems that control them, whose lives are filled with love, comedies, and tragedies—I would recommend the insect folk to your observation. Watch closely the doings of some butterfly, beetle, ant, bee, or wasp. It is not easy to study such a world of Lilliputians, but that increases the pleasure of making discoveries. There is considerable satisfaction to be found in observing creatures that have at once such interesting ways and such ecologic, economic importance.

SUMMARY

1. Of all plants and animals, insects are ecologically dominant. Five-sixths of all species, and a higher percentage of all individuals of the animal kingdom, are insects. No plant or animal, no corner of the world (except the salt ocean), is free from their triumphant hordes.

2. Insects are dominant because of. (1) Small size, as a result of which they escape enemies and exist on small amounts of food. (2) Short life cycles, allowing them to go through unfavorable seasons in an inactive stage. (3) Rapid reproduction, some insects giving rise to several million descendants in a year (which is one-twentieth of one human life cycle.) (4) Adaptability, as a result of which insects exist on foods and go through adverse conditions that no other animals could endure.

3. Some insects are direct pests, making life miserable for the higher animals about which they swarm or which they actually attack. In the Arctics swarms of flies, gnats, mosquitoes, and other two-winged insects make the summer almost unendurable for many mammals including man. In the tropics many insects live as larvæ within the bodies of mammals, and many others are carriers of disease germs. Only the temperate regions have, so far, been free enough of such pests to allow man to prosper.

4. Insects destroy about one-tenth of all agricultural crops each year. This costs the United States about $2,000,000,000 annually. Such crops

as apples, corn, and cotton are very severely damaged. Stored products are injured. Animal industries are similarly damaged.

5. As forest pests, insects eat the leaves from trees (thus starving the trees) and destroy timber. The deforestation that results may be serious.

6. As carriers of the germs of disease house flies (carrying typhoid), mosquitoes (carrying malaria and yellow fever), lice (carrying typhus and trench fever), fleas (carrying bubonic plague) and in the tropics many others are of prime importance.

7. Many insects are of no great economic importance. Some of them are distinctly beneficial to man. Many vegetables, fruits, forage, and flower-garden plants depend on insect aid in pollination and in the production of seed.

8. Scavenger insects (fly maggots, dung beetles, etc.) do good service. Predators and parasites are chief controls of many insect pests, and man is coming more and more to use them in programs of biologic control. Many insects are weed-destroyers. Insects provide such commercial products as honey, cochineal, and silk.

9. The varied structures, unusual physiologic activities, and astounding behavior of insect folks make them objects of great interest. They are commended to you for study.

DEFINE

Dominance (in ecology)
Life cycle
Pollinator

PROBLEMS

1. If it costs 50 cents per day for the food, and $50 a year for the clothing of the average person, how much do harmful insects cost the average family of five persons each year?

2. What are the names of some of the insects that attack the food materials used in your region? (They may be pests to the growing crops or to the foods in stores and in household pantries.)

3. What insects have ever been beneficial to you personally?

4. Do you think harmful or beneficial insects are of most importance to you, personally? Be careful of your answer!

5. We have discussed the relations of insects to man. Can you show how insects might affect birds, directly and indirectly?

6. How might insects be related ecologically to earthworms, directly *and indirectly?*

7. Were we correct in stating that the insects are the dominant organisms? What arguments can you produce *against* this statement?

8. Look up some book of travel in the Arctics or in the tropics. Report to the class what the traveller has to say about insects in those regions.

9. List the insects which are direct pests that have ever attacked you personally.

10. Would this be a better world to live in if all insects were exterminated? Give arguments on both sides of this question.

11. List the more common household pests that are insects.

12. List all of the insects that you can name which are of importance in spreading human disease.

13. List some of the more important insect pests in your state, and tell what damage each one does.

14. Name some insects each of which is beneficial in some respect and harmful in some other respect.

15. Are all parasitic insects economically beneficial? Explain.

16. Try to find an instance of insect damage (plant leaves that are eaten, chewed wood, infested cereals, etc.), and bring to class.

17. From special references, learn the methods of controlling some particular insect that is a common pest in your region. Report to the class.

18. Name the main phyla and classes of plants and animals which include enemies of insects.

19. Get a map of the world and make a list of countries in which the human population is greatly restricted (more so than in our own country) because of insect pests.

20. List the chapters in this book which contain special material on insects.

21. Why is so much space in this text given to insects?

CHAPTER XXXIV

BIRDS

For sheer beauty and grace and for interesting ways, the birds are hardly equalled among plants and animals. Their colors are exquisite, and their forms dainty, and they possess a marvelous skill in flying and in soaring. Their songs are the voices of friends who will come to you as you walk your paths in life. The birds are an important part of this happy world, and so you should know them.

But you should also be interested in them for another reason, which is a very matter-of-fact, dollars-and-cents reason: for birds are ecologically important creatures.

Reasons for Importance

Rapid Metabolism.—First of all, their appetites make them valuable. Birds eat whenever food is to be had. They do not have to wait, for they are always hungry. They digest food within one or two hours, on an average. This is a short time in comparison with that required for digestion in other vertebrates. A bird has to refill its stomach eight to twenty-five times a day, and thus it becomes a great controlling agent of weed seeds and insects.

The temperature of a bird's blood may be over 106°F. Its flight requires rapid respiration and uses up quantities of energy. A large amount of food is necessary to maintain such rapid metabolism.

Flight.—The flight of a bird, a superb means of locomotion, enables the creature to work benefit at widely separated places.

Now it is here in Ohio, a month or two hence it may be busy in Louisiana, Cuba, Brazil, or elsewhere. It may winter in South America, but when insects once more begin work on our plants, in the following spring, the birds will again be back here with us.

Courtesy L. W. Brownell

FIG. 345.—LIVING APPETITES

Adaptations.—Birds are remarkably adapted for finding and handling their foods. Their wings take them everywhere, into the air, out to the tips of high branches, and down onto the ground. Their bills are variously shaped for handling particular foods: fine and slender for taking insects from the surfaces of plants; very broad, stretching from ear to ear, in order to sweep insects out of the air; or large and stout and strong for crushing seeds. The eyes of birds enable them to see tiny things at great distances, and they may change focus very rapidly, as is desirable during flight. Birds of prey (hawks and owls) have strong toes (talons) for holding their foods. The tongues of woodpeckers have much-hardened tips which bear inverted barbs, and they are long and coiled about their brain-cases so they can unwind and strike deeply in extracting insects from tree trunks. Many other special structures further equip birds to capture their special foods efficiently.

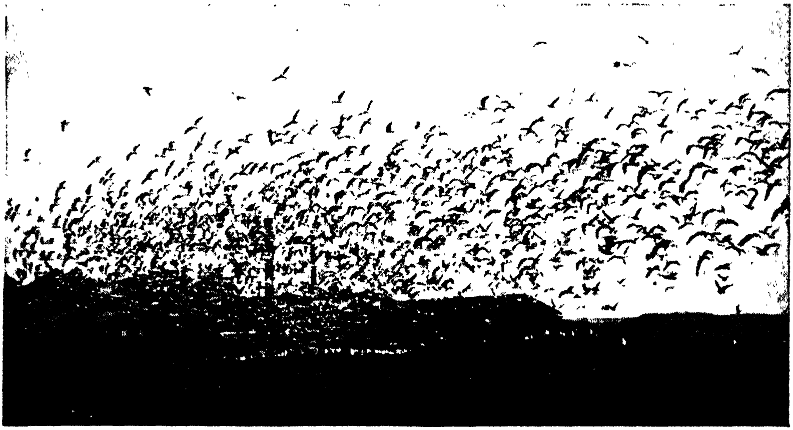


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FIG. 346.—GULLS AS SCAVENGERS AT A MEAT-PACKING HOUSE

Birds as Scavengers

Some of the largest of the birds are scavengers, engaging in the not very pleasant but important task of eating dead and decaying stuff. If a horse or cow lies dead in our southern states, buzzards are sure to gather in numbers. If dead fish accumulate on the shore of the lake, the eagle may help in the clean-up—a commendable habit, even though the bird is our national emblem!

Along the ocean coasts, and on the shores of the larger inland lakes, quantities of refuse accumulate. Bacteria, tiny crustaceans, fish, insects, and shore birds contribute to the destruction of this matter. Gulls follow ships for long distances out to sea to catch whatever waste may drop overboard. The same birds gather about our harbors to do sanitary policing. When New York City sent its garbage on scows to be dumped in the ocean, innumerable gulls gathered, and they often consumed much of the material before it had reached the open sea.

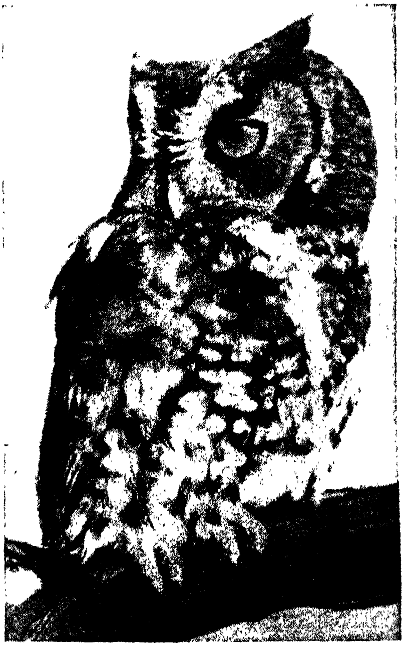

Courtesy L. W. Brownell

FIG. 347.—THE SCREECH OWL

Predaceous Birds

Another group of birds is predaceous, feeding upon animals which are caught alive. Hawks and owls and the crow are at least in part beneficial to man because they feed upon mice, rabbits, and other smaller mammals.

Few people appreciate the abundance of mice or the damage they inflict. There may be several kinds of wild mice in a region, not including the European species which inhabits our houses. Oftentimes mice eat the inner bark and cambium of trees, sometimes girdling and killing numbers of fruit trees. Getting into corn or wheat fields, they take a nibble or two from the base of each stalk and do much damage, and in corncribs and barns they injure stored grain and other materials.

The most important natural mouse-traps are the hawks and owls. These birds, of course, have an evil reputation as chicken killers, and some of them actually do damage to chickens. However, if there are eight or ten kinds of hawks and owls in your region, three or four species may feed largely upon chickens; the others will so feed only occasionally. Government experts have been watching birds all over the country, and they have examined the contents of the stomachs of thousands of hawks and owls. They report that the Cooper's and the sharp-shinned hawks are the ones that are regularly bad, and that should be killed. With other species, it should be necessary to shoot only the particular individuals that are

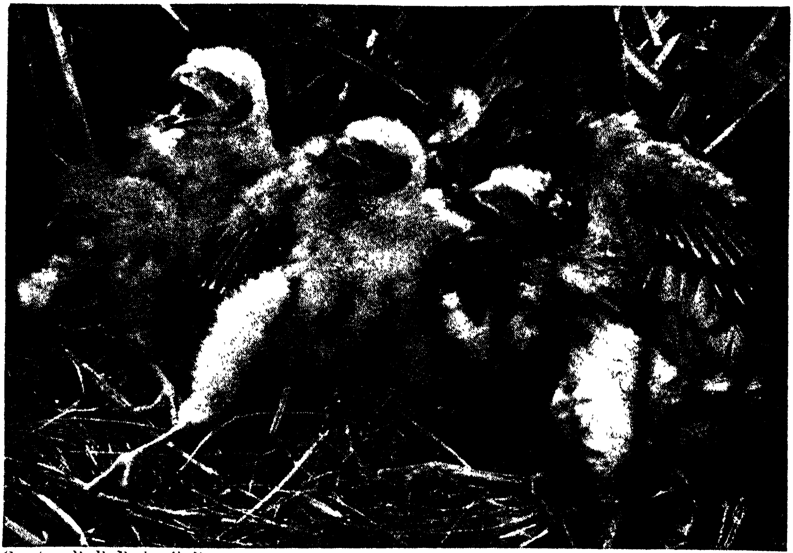
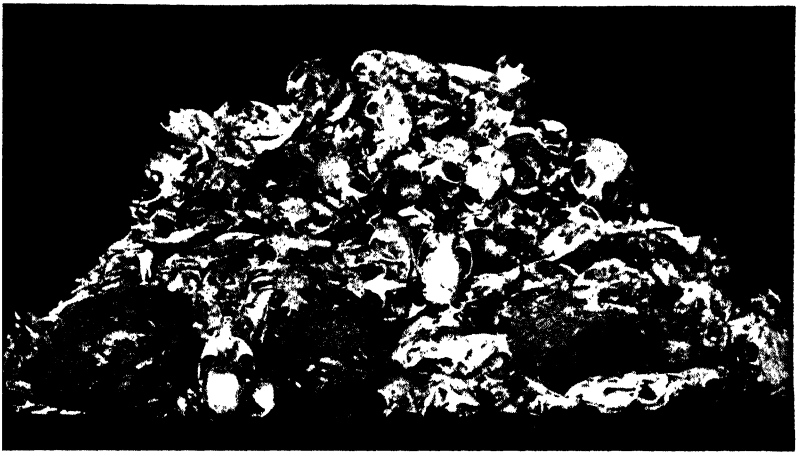

Courtesy R. B. Rockwell, Denver

FIG. 348.—YOUNG MARSH HAWKS, MEAT-EATERS

actually seen robbing the hen-yard. It is within bounds to say that if a farmer wants to protect his orchard or corn field from damage by mice he might profitably fix nesting places to attract hawks and owls to his farm.

In 1885 the state of Pennsylvania placed a bounty on the heads of these predaceous birds and certain mammals. Within a year and a half $90,000 was paid out of the State Treasury. Thereupon biologists pointed out what had been done. It was shown that in the year and a half about $2,000 worth of chickens might have been destroyed if the birds had not been killed. But it was shown that those same hawks and owls would have prevented the destruction by mice of upward of $4,000,000 worth of crops. The state had paid out $90,000 to lose $4,000,000. It should be added that the bounty law was repealed.

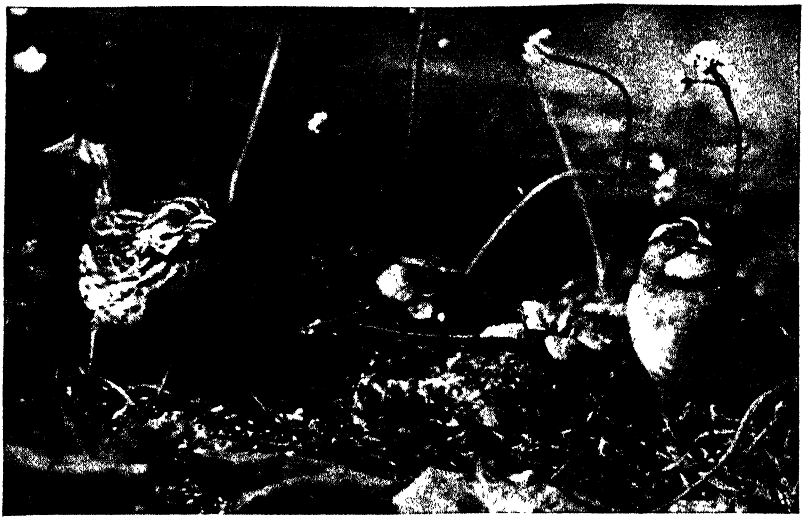


Courtesy U. S. Biol. Surv.

FIG. 349.—MOUSE SKULLS FOUND UNDER AN OWL ROOST

Weed-Destroyers

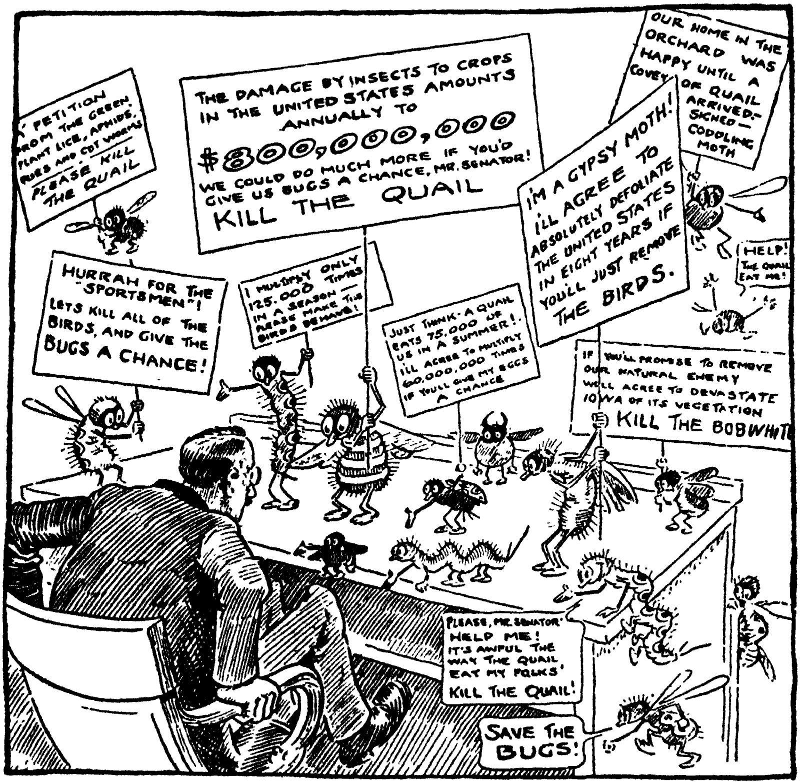
As weed-destroyers, birds will compare with all the boys and girls that can be mustered on a farm. Did you ever weed a garden? Wasn't it hard work? And after it was done, didn't more weed seeds blow in from your neighbor's yard, or from the next field, or from uncultivated places that were some distance away? To bring permanent results, weed-destroyers must be on the job day in and day out, all of the time, and they must take care of every garden in town and the rest of the places which are spreading weed seeds. Seed-eating birds, with their nothing-else-to-do-but-to-eat-seeds program, are consequently able to keep down weed pests—if we protect the feathered creatures and allow them to live.



Courtesy A. A. Allen, Cornell Univ.

FIG. 350.—SEED-EATERS, THE SONG AND WHITE-THROATED SPARROWS

The seed-eaters belong chiefly to the sparrow (the so-called finch) family. All these birds are equipped with broad, heavy beaks which are meant just for crushing seeds. In this family are the song sparrow and the field sparrow, the tree and chipping and swamp and fox and grasshopper and savannah and vesper sparrows, the beautiful white-crowned, golden-crowned, and white-throated sparrows, and many others. You didn't know there were so many kinds of sparrows? Some of them visit you only in migration seasons, but many of them are common in your region during most of the year.


A PETITION FROM THE GREEN PLANT LICE, APHIDS, FLIES AND CUT WORMS — PLEASE KILL THE QUAIL
THE DAMAGE BY INSECTS TO CROPS IN THE UNITED STATES AMOUNTS ANNUALLY TO $800,000,000 WE COULD DO MUCH MORE IF YOU'D GIVE US BUGS A CHANCE, MR. SENATOR! KILL THE QUAIL
OUR HOME IN THE ORCHARD WAS HAPPY UNTIL A COVEY OF QUAIL ARRIVED:- SIGNED — CODDLING MOTH
I'M A GYPSY MOTH! I'LL AGREE TO ABSOLUTELY DEFOLIATE THE UNITED STATES IN EIGHT YEARS IF YOU'LL JUST REMOVE THE BIRDS.
HELP! THE QUAIL EAT ME!
HURRAH FOR THE "SPORTSMEN"! LETS KILL ALL OF THE BIRDS, AND GIVE THE BUGS A CHANCE!
I MULTIPLY ONLY 125.000 TIMES IN A SEASON — PLEASE MAKE THE BIRDS BEHAVE!
JUST THINK - A QUAIL EATS 75.000 OF US IN A SUMMER!. I'LL AGREE TO MULTIPLY 60,000,000 TIMES IF YOU'LL GIVE MY EGGS A CHANCE
IF YOU'LL PROMISE TO REMOVE OUR NATURAL ENEMY WE'LL AGREE TO DEVASTATE IOWA OF ITS VEGETATION KILL THE BOBWHIT
PLEASE, MR. SENATOR' HELP ME! IT'S AWFUL THE WAY THE QUAIL EAT MY FOLKS' KILL THE QUAIL!
SAVE THE BUGS!

Courtesy W. A. Ireland and the Columbus Evening Dispatch

FIG. 351.—THE SENATOR RECEIVES A DELEGATION OPPOSED TO THE BIRD-PROTECTION BILL

There are inaccuracies both in the statements and the portraits of the insects, but the cartoonist has cleverly expressed the idea.

Also belonging to the sparrow family are the juncos which form the flocks of "snowbirds" in the winter, the indigo and western buntings, purple finches, goldfinches, and several larger birds like the cardinal redbirds, the towhee (chewink), dickcissel, and grosbeaks. All of these are seed-eaters. Some birds of other families, like the catbirds and robins and thrushes, feed upon seeds at times, but the great weed destruction is accomplished by the sparrows.

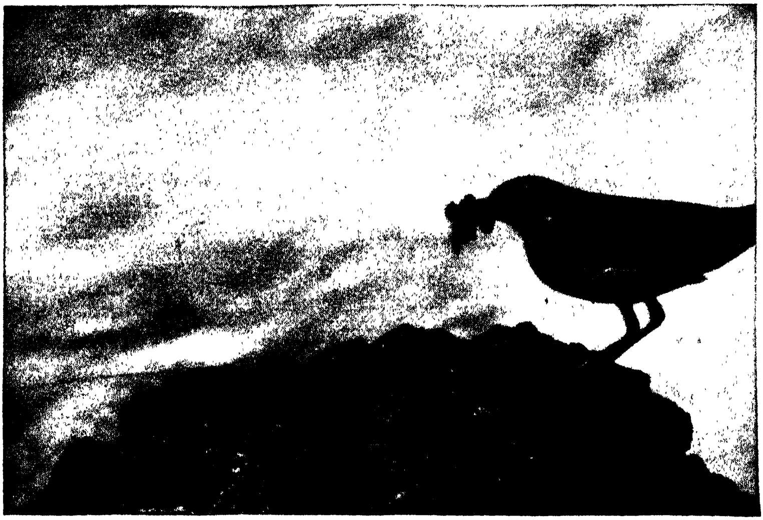
A fox sparrow was seen to eat 130 seeds in three minutes. One dove's stomach contained 9,200 seeds. A certain bobwhite (the "quail" of the Middle West) had eaten for one of its daily dozen meals about 300 seeds of smartweed, 500 of sorrel grass, 700 of mercury, and 1,000 of ragweed, a total of 2,500 seeds of weeds that are common in our gardens. Even though not all of these would have grown into large plants, it is probable that the single meal of that particular bird prevented several hundred plant pests from developing. Do you wonder that some of us do not go "quail" hunting, and prefer not to eat quail at the table? The bird can kill weeds faster than I can!

There is the goldfinch, that little yellow bird with black wings and cap, that goes flying through the air in great wavy lines, twittering as he goes. He is also called a yellow bird, or wild canary, or thistle-bird. The last name is a good one, for thistles, the extermination of thistles and other downy-seeded plants, are a chief concern with that bird. He eats the seeds of thistles, and he gets rid of others by lining the nest with thistle-down, waiting until July or after, until most of the other birds are done nesting, when thistle-down may be obtained. I express my discomfort when I step on a thistle out in the fields; but I forget the number of times I have stepped on soft grass where there were no thistles because goldfinch had eaten the thistle seed.

Insect-Feeders

Most important of all are the birds that feed upon insects. You know how destructive some of the insects may be as they feed upon food crops and forest trees. Nevertheless, the pests have to keep watch, or a bird may get them before they're grown up.

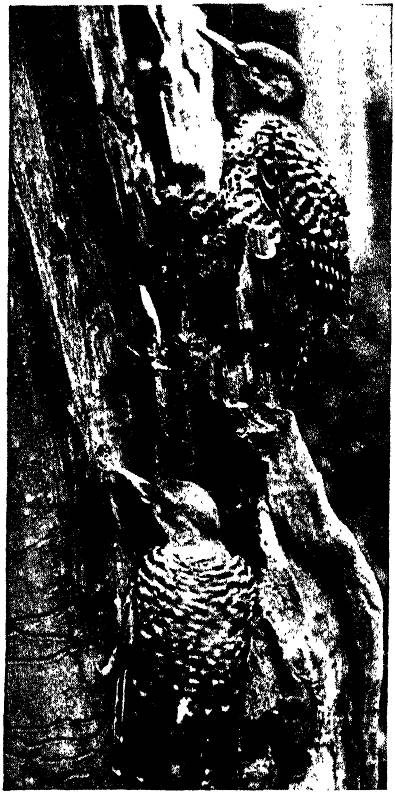
If the insects are in the air, there are birds that fly with their mouths continually ready to catch them. The swift soarings and turnings of the swallows and martins are not performed just for the fun of it. Swallows fly to swallow flies! The chimney swifts, the whip-poor-wills, and the night-hawks also catch insects on the wing. Three thousand mosquitoes were found in the crop of one night-hawk. The flycatchers (including the king-bird, phoebe, pewee, chebec, and some others) perch in the open, waiting until insects come by, and then they make sudden darts and snap the pests out of the air. You may reduce the mosquito nuisance in your region by attracting and protecting such birds.



Courtesy A. A. Allen, Cornell Univ.

FIG. 352.—LOUISIANA WATER-THRUSH WITH A MOUTHFUL OF INSECTS

If the insect lives on the surface of a plant, eating the leaves or the stems, then the control belongs to the vireos (a half dozen kinds in each region), the wrens and tits (another half dozen kinds), the chickadees, the kinglets (two kinds), or the wood warblers. There may be thirty or more species of warblers in a locality on a late spring day. All of these warblers are small birds, smaller than an English sparrow; most of them are weak singers that never warble at all; but most of them are attractive because of their bright colors. They are beautiful creatures, nervous, continually flitting about in bushes or trees, everlastingly hunting for something to eat. They are among the most beneficial of our birds.



Courtesy R. B. Rockwell, Denver

FIG. 353.—BUG-HUNTERS, BEGINNING EARLY

Young red-shafted woodpeckers, Colorado.

If the insect is hidden beneath the bark, the keen ear and eye of some bird will discover it. It may be a chickadee, or a creeper, a white-breasted or red-breasted nuthatch, or one of the dozen or more kinds of woodpeckers that will perform this function.

If the insect lives in the ground, there are still a few birds that will search for it. The stomach of one flicker (a large woodpecker, also called a yellow-hammer or high-hole) was found to contain 1,000 ants of a ground-inhabiting species.

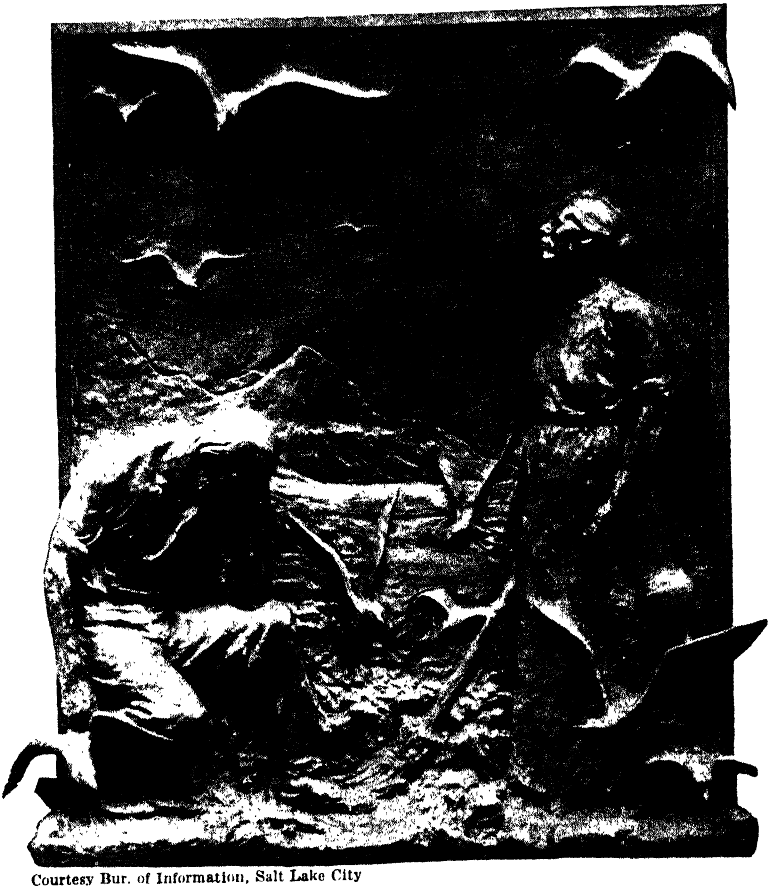
Importance in Conservation

Let me tell you a story to illustrate the importance of insect-eating birds.

My grandmother went West with the early pioneers, west from New York state to Kansas, and again westward into Utah. Nine long months it took to cross the prairies and plains, and the deserts and the mountains, moving in ox-drawn prairie-schooners. Then in time they toiled over the rugged Wasatch and down through the canyons and out into a veritable "Land of Promise," the valley of the Great Salt Lake of Utah. Here they planted their crops. The soil was fertile, water was abundant for irrigation, and there was promise of an abundant harvest.

But one day the settlers looked at the mountains and beheld a dark mass moving over them. On it came, with a hop and a jump. They were insects, great, dark-bodied Mormon crickets, wingless insects more closely related to the katydids than they are to our Eastern crickets. Here they came to feed on the ripening fields. Instantly they covered everything. Not merely an insect here and another one there, but insects everywhere, sometimes layers deep, fighting to get at the green plants that lay underneath. Practically anything that had soft plant fiber in it was food for the invading hosts. Green fields were brown within a few hours; food was eaten off of spread tables; straw hats were attacked while the men still wore them; window curtains, table covers, articles of clothing, were eaten within the log cabins. The settlers spent their day boiling water to pour on the ground in an effort to destroy some of the insects. Chickens and hogs were turned loose to help in the fight. Brush fires were built and the insects swept into them. But still crickets swarmed everywhere.

Toward the end of the second day, as the weary folks looked to the north, they saw a cloud—a cloud now the size of a man's hand, a cloud that grew with a rush and a roar, a cloud that covered the sky and hung twixt heaven and earth, ready to fall on the torn fields. Was it wind, or snow, or



Courtesy Bur. of Information, Salt Lake City

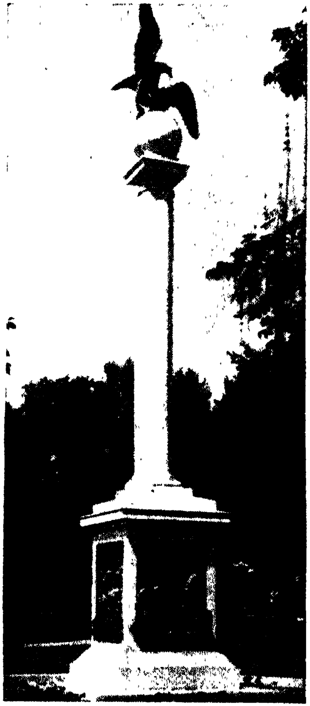
FIG. 354.—THE GULLS COME TO SAVE THE LAND

rain, or more insects? Another invasion of insect hosts, and what would become of the remnants of the crops? Would the colony perish?

At the entrance to the Temple Grounds in Salt Lake City today, you may see a great, tall shaft. At its base are carved bronzes, telling the story I have told. There is the prairie-schooner, toiling across the plain. There is the Land of Promise, rich with ripening grain. There are the ruined fields, the insect-covered furrows, and the man who has fought all day and now is sunk exhausted. Only the woman with the child at her hand still has courage to lift her head and look into the cloud that is falling. And she sees what must have made her cry out even with joy.

The gulls that nest at the far north of the Great Salt Lake, fifty miles from the destruction, have come in numbers to save the land. Their white, rose-tinged forms are dropping onto the fields; the insects are being devoured. It is fortunate that the gull, in common with many other birds, can eat and eat until its crop is full, and then if food is still available it can vomit up what it has eaten and go at the battle again!

Do you wonder that at the top of the shaft there are two bronze birds, and that the gull became an emblem of Utah, protected by a uniquely stout law?



Courtesy Bur. of Inform., Salt Lake City

FIG. 355.—THE SALT LAKE GULL MONUMENT

Birds may not always be so dramatic in their deliverances as were the Salt Lake gulls, although essentially the same thing occurs day after day in the regions in which we live. Tiny, unseen, but mighty enemies are attacking our foods as they grow. But the birds are helping save our crops.

SUMMARY

1. Birds are among the most beautiful of living things. To know them by name will add much to your happiness. They are also worth knowing because they are ecologically important.

2. Their rapid metabolism (rapid digestion, rapid respiration, high body temperature, great activity) demands that they consume considerable food many times a day. When the food consists of weeds, harmful insects, or other pests, then feeding birds become highly valuable.

3. The remarkable powers of flight possessed by most birds also account for their importance.

4. The adaptive structures of bird bills and feet allow them to take their food in very efficient fashion.

5. As scavengers, such birds as buzzards, eagles, and gulls are of great value.

6. Predaceous birds, like hawks, owls, and crows, feed largely on mice and other rodents. A few species feed largely upon chickens, and some individuals of other species become chicken thieves; but most species are mouse-feeders. Mice do untold damage to orchard and grain crops, and their bird controls deserve our protection.

7. The many species of birds which belong to the sparrow family are seed-eaters, equipped with powerful bills for crushing seeds.

8. The insect-eating birds are perhaps as important as parasitic and predaceous insects in the control of insect pests. Some birds are equipped for finding and capturing insects in one place, other birds for capturing insects in other places.

9. During pioneer days in the Rocky Mountain and Great Basin areas, grasshoppers and crickets frequently migrated in great numbers to feed upon the settlers' crops. Often birds followed the insects and helped reduce their numbers. Gulls on several occasions helped save the crops in the Great Salt Lake Valley. Similarly, even if less dramatically, birds continually help us in our fight with the insect world.

PROBLEMS

1. How many kinds of seed-eating birds do you know when you see them? Briefly describe them.

2. How many kinds of insect-eating birds do you know? Briefly describe them. Do they get their insects from the air, plant surfaces, or elsewhere?

3. Seed-eating and insect-eating birds are protected by a treaty be-

tween Canada and the United States. Why was it necessary to have the two countries agree on the law? What other countries ought also agree on the treaty?

4. Explain what relation there might be between the birds of Pennsylvania and the height of the Mississippi River in Louisiana.

5. How many kinds of scavenger birds do you know when you see them? Briefly describe them.

6. Make a list of the birds which you know that seem to do more economic damage than good.

7. Find out what you can concerning the economic importance of the crow.

8. Find out what you can concerning the economic importance of the robin.

9. What are the relative merits of the robin and English sparrow? There is a great deal to be said on both sides of this question!

10. It has been said that if all birds were exterminated, all other kinds of life would soon disappear from the earth. Show how this might happen.

11. Biologists now feel that the above is a greatly exaggerated statement. Show why, in actuality, no such disaster would follow the extermination of the birds.

12. Compared with a hundred years ago, are birds now more important or less important in this country? Carefully explain.

13. In the cartoon which is Figure 351, which of the placards are scientifically correct, and which are inaccurate?

14. From other references, find out how many different species of birds occur in your state. As far as you can find out, compare the number of birds with the number of species of reptiles, insects, mammals, amphibia, and fish in your state.

15. List the chapters in this book which contain special material on birds. How does it compare with the number of chapters considering insects? Why?

16. In your state, which of the wild birds are we ever justified in eating?

17. How many kinds of domesticated birds can you name?

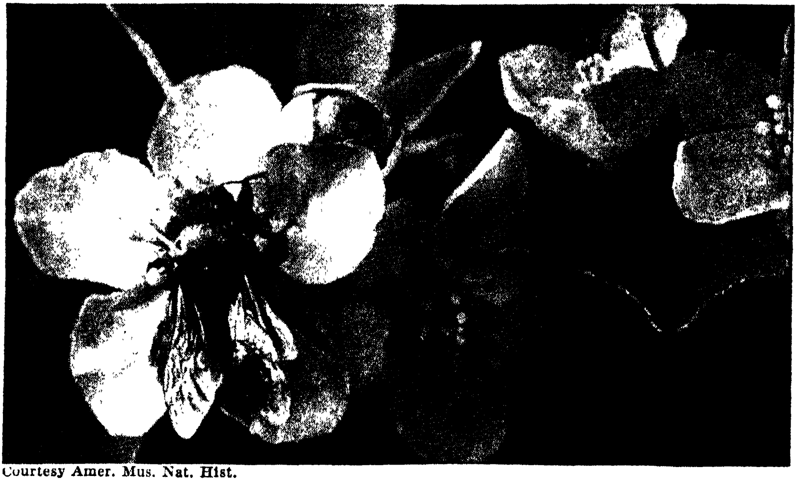
18. What non-American birds are introduced in your state? What is the economic importance of each?

19. List the phyla and classes of plants and animals which contain enemies of birds.

CHAPTER XXXV

INSECTS AND FLOWERS

As an illustration of the very intimate way in which two groups of organisms may be related, consider how insects distribute the pollen of flowers. Here is one of the romances of the out-of-doors, every act of which you may readily observe for yourself in the woods and the fields.



Courtesy Amer. Mus. Nat. Hist.

FIG. 356.—A BUMBLEBEE AMONG APPLE BLOSSOMS

Insects go to flowers to gather nectar, that sweet, sugary liquid that lies usually inside at the base of the petals. This nectar, after preparation by the bee, becomes the honey of the hive. While gathering nectar, some bees and wasps may also collect pollen, which they take home as food.

But the matter of importance to the flower is the fact that insects in coming and going incidentally transfer pollen from the stamens to the pistils of plants. After this, fertilization may occur, and seeds may be formed. The nectar and other things, as we shall see, are only the invitations, the baits, the refreshments that are served to the six-footed guests. The guests get their invitations because they are capable of working for their hosts.

Some plants depend upon the wind to carry their pollen. This is true of grasses and of most trees. Aquatic plants and other plants growing near the water's edge may have their pollen carried on the surface of the water. These are very wasteful methods, most of the pollen grains never reaching the pistils at which their journeys should end. Plants depending upon such means must have enough pollen and quantities to spare.

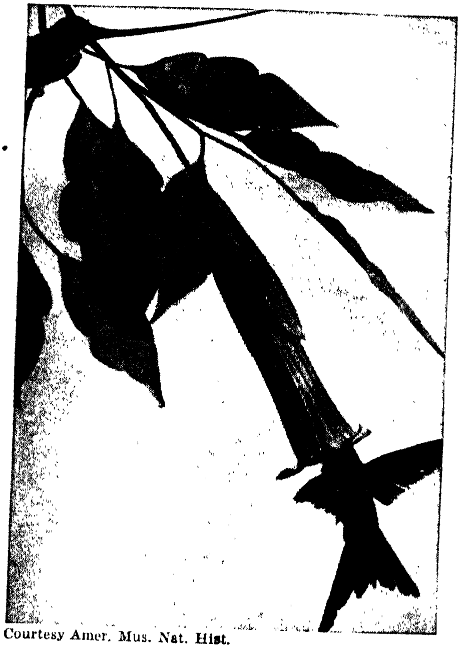
The more certain transfer of pollen is accomplished with much less waste by insects, humming-birds, bats (in South America), snails, and a few other animals. Of these, the insects are by far the most important. Bees of all kinds, slenderish honeybees, fat bumblebees, many large and small kinds of wild bees, and the numerous species of wasps are the most common insect pollinators. Some flies, long-tongued moths and butterflies, and some insects of other groups also engage in the work.

Importance of Cross-Pollination

Any process by which pollen is carried from a stamen to a pistil is called *pollination.* If the pollen passes from a stamen to a pistil of the very same flower, the process is called *self-pollination.* If the pollen of a flower goes to the pistil of another flower (of the same species), the process is called *cross-pollination.*

Many plants do not form good seed by self-pollination.

If netting be so stretched over a bed of red clover that bumblebees or other such insects cannot get at it, the seed resulting from self-pollination will amount to only about one-half of one per cent of the production normal with cross-pollination. Only heavy bees can force a way inside the closed petals of red clover, and the bumblebee has an especially long tongue for reaching to the bottoms of the long tubes of the flowers. The red clover (not other clovers) is therefore chiefly dependent for cross-pollination upon this group of insects. Darwin discovered this fact, but some years later the British Government forgot it when it carried red clover seed to New Zealand. The climate and soil conditions there were favorable for the plant, the authority of a great Empire was behind the project. But long-tongued bees were lacking in that country. When the crop failed to set sufficient seed to maintain itself, bumblebees had to be imported with the next shipment of seed. Since which time clover has flourished there!

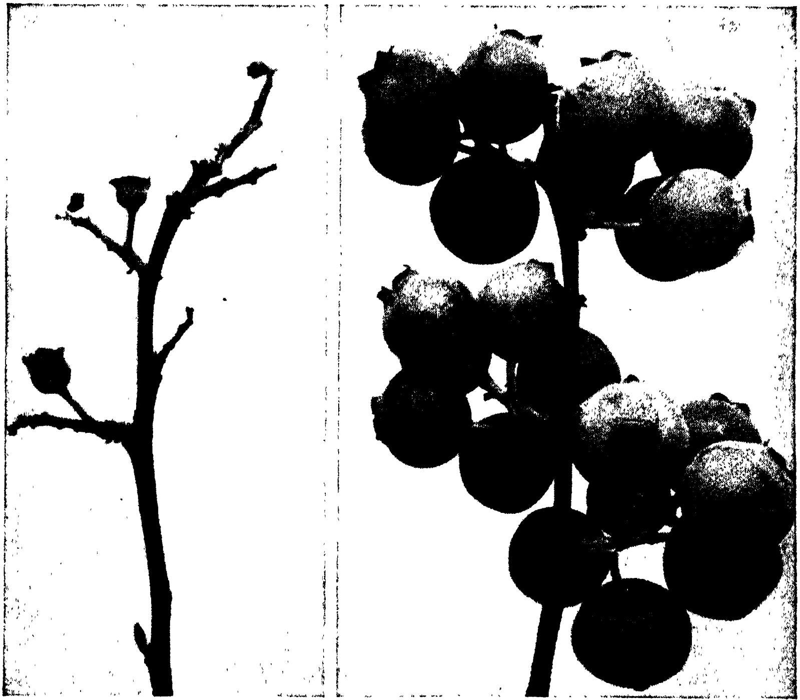


Courtesy Amer. Mus. Nat. Hist.

FIG. 357.—HUMMING-BIRDS ARE SOMETIMES CARRIERS OF POLLEN

Numerous other species of plants are as dependent upon cross-pollination as the red clover. Many of the larger, more brilliantly colored flowers are in this group. Many others (dandelion) produce good enough seed by self-pollination.

Some plants (wild geranium, fireweed) ripen their pollen after the pistils have functioned and died, in that way preventing any possibility of self-pollination. Some flowers have stamens located so far below the pistils that there is no chance of pollen being shaken from them onto the pistils of the same flower. This is a common arrangement in our wild flowers.



Courtesy U. S. Bur. Plant Industry

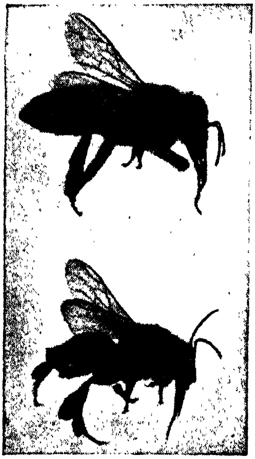
FIG. 358.—THE IMPORTANCE OF CROSS-POLLINATION

Blueberries (left) from self-pollination and (right) from cross-pollination. About natural size.

The insect has many special structures by means of which it accomplishes cross-pollination. There are special mouthparts, hairy bodies, and special sense organs. Similarly, flower structures insure cross-pollination, the forms, colors, and odors of many flowers serving to attract insects. Insects are adapted to flowers, and flowers to insects. It is impossible to consider one group without considering the other.

Insect Adaptations

Mouth-Parts.—Insects that are concerned with pollination have mouth-parts especially adapted for sucking nectar. It is certain that such mouth-parts are recent developments in insect evolution. The mouth of a bee has all the parts of a chewing mouth, but several of the parts have been changed so they now make an ideal sucking tongue. At the same time the jaws of the insect are shaped like trowels, and they are used for shovelling pollen.



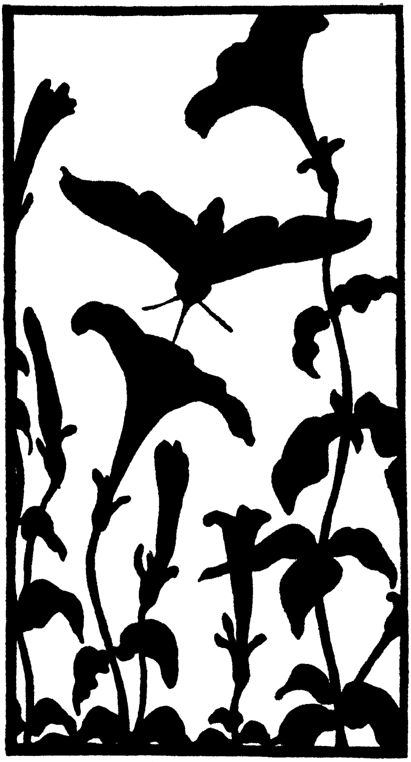
Courtesy A. I. Root Co., Medina, O.

FIG. 359. — BEES, WITH EXTENDED MOUTH-PARTS
Equipped for sucking nectar.

Butterflies and moths, some of them, have peculiar mouth-parts which form long and slender, hollow tubes that roll up like watch-springs against the faces of the insects. Watch the sphinx moths, those heavy-bodied creatures that fly about the garden at dusk, resembling humming-birds. They pause in mid-air, hovering a full inch or two before a honeysuckle flower. Ah! Did you see it? Or was it too quick for your eye? Like a flash the long tongue unrolled, and touched and drained the nectaries in the depths of the flower. The creature darts off to the next blossom before you realize what it is about. You may unroll the tongues of dead specimens of these moths, if they are not too dry. But you must try to see the performance of the live animal. In the United States there are sphinx moths with tongues six and seven inches long. Darwin, when shown an orchid flower from Madagascar that had a closed tube nearly twelve inches in length, predicted that some insect would be found with a similarly elongated tongue. Sure enough! Some time later a sphinx moth with a twelve-inch tongue was discovered in that country.

Honeybees.—Worker bees are all hairy. This fits them as pollen carriers. Drone bees that do not work are more naked fellows. They would not use hairy clothes if they had them. But watch a worker as it goes in and out of the flowers in the garden or the fields. Notice how yellow its body becomes with pollen.

The bee combs the pollen off its body with its legs. There are combs of spines and stiff hairs on one of the joints of the middle and hind legs which gather the pollen and pack it into pollen baskets. The baskets are smooth areas on the largest joints (the *tibiæ*) of the hind legs, with stiff hairs along the edges of this basket which prevent the pollen from falling out. In addition, honeybees have large, spiny-rimmed spaces between the joints of their legs, and pollen also accumulates there. Most of the pollen thus gathered will be used in feeding the young bees, but some grains will fall out onto the

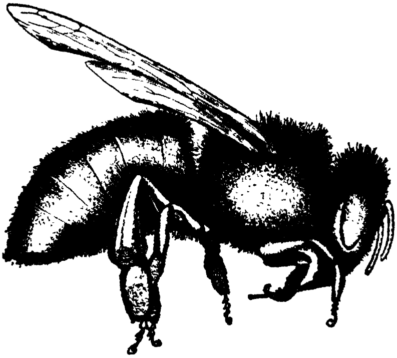


M. L. Voorhees, Del.

FIG. 360.—LONG-TONGUED MOTH AT A FLOWER

pistils of other flowers, and that is enough to accomplish what the plants need.

Insect Senses.—Most insects have remarkable senses of smell. In comparison, a bloodhound is clumsy at following a trail. Even the faintest odors of flowers are sufficient to attract insects from great distances.



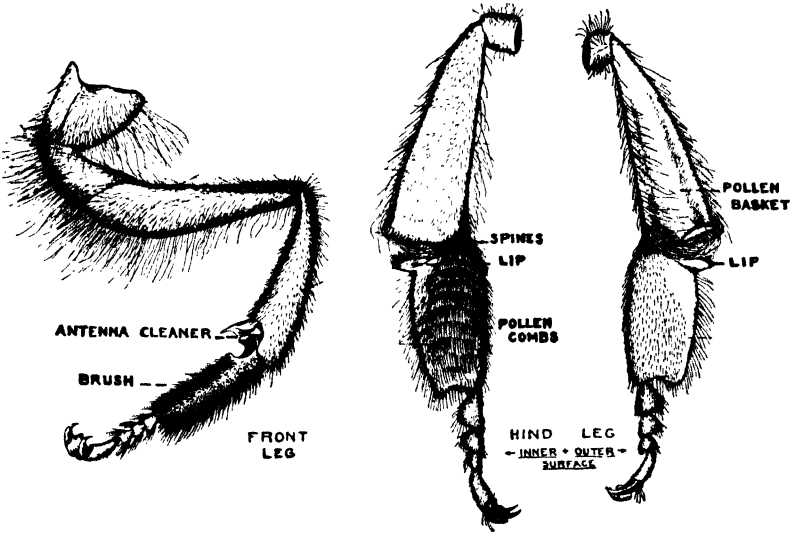
Courtesy U. S. Bur. Entomology

FIG. 361.—HONEYBEE HANDLING POLLEN

Insects have, in general, very poor sight, and cannot see more than shadowy outlines of objects three or four inches away. How much of the color of flowers is evident to them is not wholly a settled question, but if honey is placed on pieces of glass of different colors, the bees will soon find it (by smell), and they will usually go to the honey on the blue and purple glasses, proving that they can distinguish colors and that they have color preferences. Both the colors of flowers and the color senses of insects are adaptations which bring the two organisms together.

Perhaps you have wondered what keeps an insect from carrying the pollen of one species to a different species of flower. Quantities of pollen and of insect energy would be wasted by such a distribution, for most pollen will not grow on the wrong kind of pistil. However, if you will watch an insect—a great, heavy bumblebee that can be easily seen, and that will not fly too fast—you will find that she has only a few names on her calling list for each trip. After becoming loaded, the bee returns to her nest, deposits the nectar, dusts the pollen off her clothing, and starts out again, perhaps this time to visit other species. It is true that the insects do at times go astray and depart from this rule, but such exceptions constitute only three or four per cent of all their visits. Verify this for yourself by following bees in the fields and the meadows.

Special Relations.—Certain species of insects have even more special types of behavior that connect them very closely with particular species of flowers. The **yuccas**, so common in our Southwest, depend each upon a single species of tiny, white moth for cross-pollination. The so-called Spanish bayonet, grown everywhere in cultivation, is a yucca. Working after dark, a moth bores a deep hole into the ovary at the base of the pistil of the yucca flower, and there she lays her eggs. Then, most astounding of performances, she proceeds to the top of the pistil, and into it she pushes and packs pollen. This is the only way in which pollen can



Courtesy U. S. Bur. Entomology

FIG. 362.—HONEYBEE LEG ADAPTATIONS

Cleaners and *brushes* on the front legs remove the pollen from the bodies of worker bees. The *combs* of the hind legs (inner surfaces) take it from the front legs. The *spines* remove it from the combs of the opposite legs, piling it on the lips. Finally the *lips* push the pollen into the pollen baskets (outer surfaces of the hind legs).

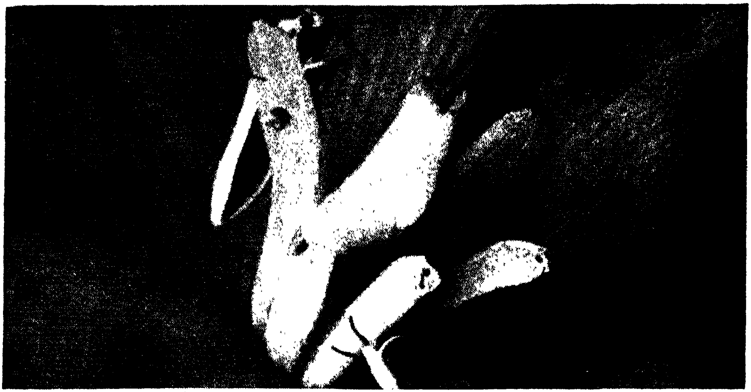

Courtesy W. M. Savin, N. Y.

FIG. 363.—YUCCA MOTHS GATHERING POLLEN
Much magnified, showing part of a single flower from a cluster.

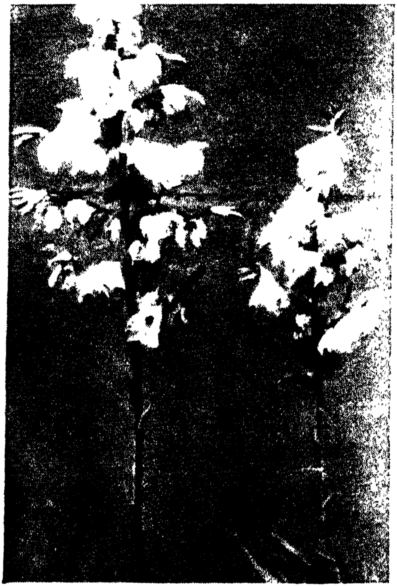

Courtesy W. M. Savin, N. Y.

FIG. 364.—YUCCA PLANTS IN FLOWER
This species is common in cultivation throughout the United States.

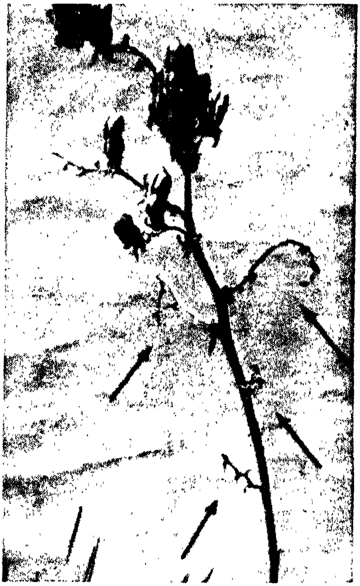

Courtesy W. M. Savin, N. Y.

FIG. 365.—THE YUCCA MOTH NECESSARY FOR POLLINATION
Moths were excluded from the lower flowers of this plant.

reach these flowers. The young larval insects that hatch in the ovaries of the flowers feed upon the developing seeds, but plenty of seeds escape to mature.

As intimate a relation exists between the flowers of certain kinds of **figs**, and a tiny parasitic wasp. Many varieties of figs, including the Smyrna fig, never produce edible fruit except where these wasps occur and perform the complicated processes that result in cross-pollination. Few people realize this as they eat the fruits. In order to get those varieties of figs to grow in the United States (Southern California, etc.), it was necessary to import the insects from Western Asia.

Flower Adaptations

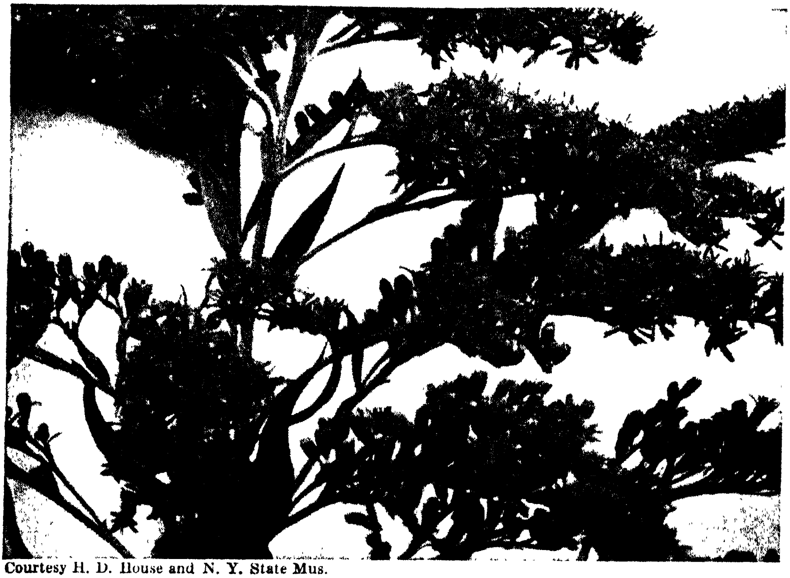
Colors.—As already suggested, the colors of wild flowers are not just for looks, for human eyes to see. That may be true of many cultivated things that the plant breeder has helped create. But the colors of the flowers of the fields and the woods are adaptations which attract the insects. The brighter the colors, the better they attract. Perhaps some of the finer markings on the petals of flowers are also guides to the insects.

Flowers that bloom at night (evening primroses, bladder campions) are evident in the dark because they are always light yellow or white in color.

Arctic and mountain-top flowers are unusually brilliant in color, and thus they attract the few cross-pollinating insects that exist in those regions.

Compound Clusters.—Small flowers that, alone, are too tiny to make a color show, are often grouped into compound heads, conspicuous at a considerable distance. This is so with clovers and wild carrots. More tightly packed flowers occur among the *composites* (goldenrods, daisies, thistles, sunflowers, dandelions, asters, etc.). Heads of these plants are not single flowers, as they may at first seem, but great bouquets of hundreds of tiny flowers. Each white ray of the daisy is a separate flower, and a hundred or so tubular flowers are massed in the yellow center. Single flowers of such a size would often go uncourted; when massed, they attract no end of suitors.

Closed Flowers.—Many flowers have petals joined together to form closed tubes. Did you ever stop to realize the advantage in the shape of an Easter lily? The lily shuts out the insects which would slip in between unconnected petals to steal the nectar, and caters only to those species with tongues long enough to reach down to the nectaries. Forced to enter at the top, the visitors have to pay their regards to the stamens and pistils that stand in the doorway.



Courtesy H. D. House and N. Y. State Mus.

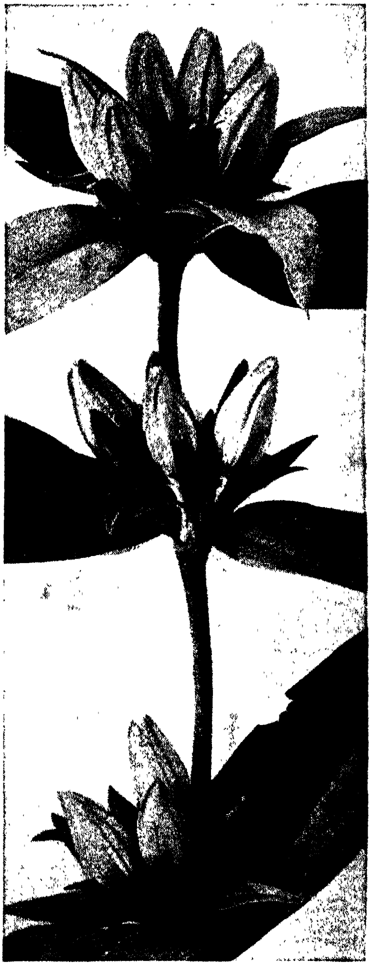
FIG. 366.—LOOK CLOSELY AT THE HEAD OF A GOLDENROD

Each smallest part really contains a number of tiny flowers.

Odors.—Then there are the odors of wild flowers. They are usually delicate, sweet, attractive to the human as well as to the insect. In some instances (carrion smilax, an Eastern species of purple trillium, skunk cabbage) they seem too strong and rank and repulsive to our senses, but even then they attract those few insects that occur early in the spring, namely the flies that delight in such odors.

Perhaps the most remarkable adaptation of odor occurs among the evening primroses, species of which are common weeds in waste lands over the country. Their pale yellow flowers are usually closed through the day, opening after sundown. Then, and not until then, a peculiarly sweet fragrance may be detected coming from the flowers, and this becomes stronger through the dewy night. At sunrise the odor fades, not to develop again until the following evening. Thus the attractions of the flower are reserved for the trade of night-flying visitors, chiefly moths.

Ant Traps.—Ants are thieves of nectar. They are so small they can crawl into many flowers without coming into contact with their stamens or pistils. Flowers that hang their heads (such as violets) are, however, invaded with difficulty by these insects. Spines and



Courtesy H. D. House and N. Y. State Mus.

FIG. 367.—THE CLOSED GENTIAN

Because the petals never spread open, all but heavy-bodied insects are kept from the nectar.

small leaves clustered directly beneath the flower heads (as in thistles) help to keep out ants as well as to discourage browsing cattle. Inverted spines and sticky hairs on the stems keep out many a maurauder.

The wild lettuces, which are common weeds in gardens and waste places, and the cultivated lettuces if allowed to go to seed, have such thin skins on their stems that the claws of ants sometimes strike through. You may see how this is done by using your finger-nail. The white, thick sap that oozes out becomes hard almost as soon as it is exposed to the air. A little searching will disclose lettuce stems with dead ants stuck tight, early in their thieving careers.

FIG. 368.—SKUNK CABBAGE

Special Structures.—Many flowers like wild roses and apple or cherry blossoms are wide open to any insects that come along; but there are some flowers that have very special devices which accomplish cross-pollination in very special ways. The **milkweeds** have their pollen in masses that are shaped like saddle-bags. The fly or bee or wasp visitors get their feet hopelessly entangled in the bags, and have to jerk the things out of the flowers and carry them about for hours, scattering pollen wherever they go. You can imitate this easily enough by using a pin-head on the next milkweed flower.

The **laurels** (mountain laurel, lambkill) have their stamens bent almost double, with their heads tucked away into the little pockets that are inside each petal. When these stamens are touched they spring out of the pockets with considerable force, thereby throwing pollen several inches. Bees that spring the traps are, of course, thoroughly dusted.

Courtesy National Park Service

FIG. 369.—A FIELD OF EVENING PRIMROSES

The **horsebalm** (richweed), an inconspicuous but common mint of the woodlands of the Eastern United States, has four small but only one large petal. The bumblebee, attracted long distances by the strong, citronella-like odor of the flower, naturally alights on this petal, but its deep fringing makes it too weak to support her, and off she tumbles. Now, what advantage is it to a flower to dump off its most welcome guests? Investigate the matter for yourself. The performance is easily observed, wherever the plant grows. Not to be cast away, the bee throws up her legs to grasp whatever is handy. This means the long stamens that protrude above, and the violent shaking they receive dusts the bee very effectively.

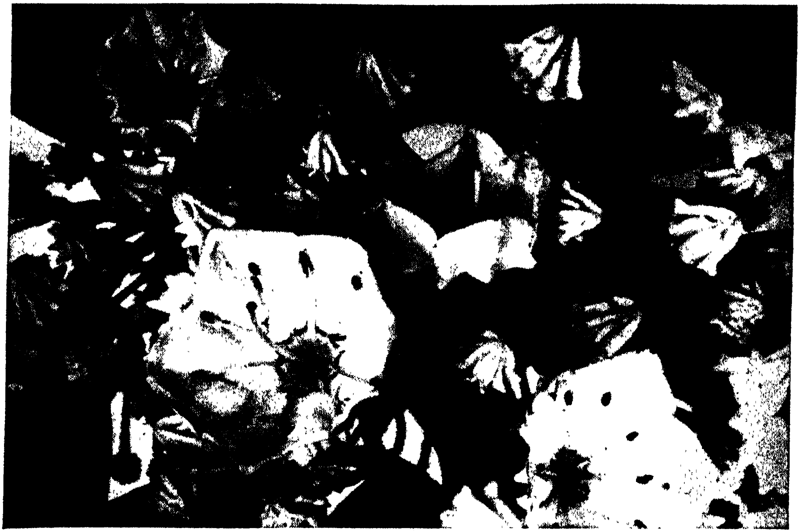
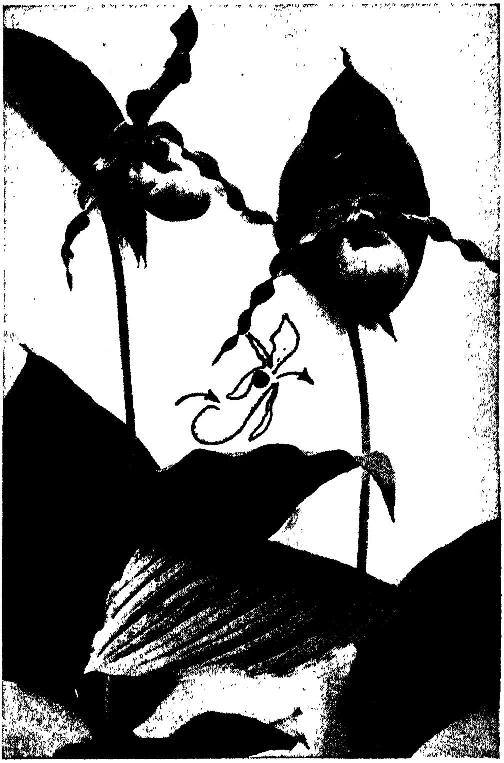


Photo by M. C. Dickerson. Courtesy Amer. Mus. Nat. Hist.

FIG. 370.—THE BENT STAMENS OF THE MOUNTAIN LAUREL

One of the very nice arrangements is with the **lady-slipper orchids.** Several of these grow wild in rich woods and the florist has others that have come from the tropics. The plants invite the bee to enter through the very conspicuous front door. Inside the flower, the visitor is rewarded with a due amount of nectar. But she is also trapped! The bowl of the slipper is closed, and the walls are too steep and too curved for her to climb back to the entrance. The room is too scant for her to get start enough to fly out. Hear her buzz!

But at last she has found the passage to the back door, the only way by which she may leave. It is small and narrow, but sufficient. Still, in entering the passage she must bump her head against the protruding pistil on which she will leave a few pollen grains brought from the neighboring flower; and farther along, before she can get through the passage, she will have to bump into the stamens and become dusted with pollen. Every time it is so. You can watch the whole performance for yourself, out in the spring woodlands.



Courtesy H. D. House and N. Y. State Mus.

FIG. 371.—POLLINATION IN THE YELLOW LADY-SLIPPER

Origin of the Relations.—So successful are the ways by which plants attract insects that it is difficult to speak of them without using language that suggests that the flower deliberately, consciously, prepares its attractions. That, of course, is not so. The adaptations have originated blindly, in the orderly processes which we call evolution.

But we know that in the geologic ages before there were any higher insects, particularly bees and wasps, there were no plants with flowers more showy than those of the present-day pine trees and grasses; and similarly before there were any showy flowers there were none of the higher insects. The two groups developed at the same time, many millions of years ago. Their ecologic relations date back as far as that, and will continue as long as both parties exist.

SUMMARY

1. As an illustration of an intimate ecologic relation between two groups of organisms, we may consider the relations of insects to pollination in flowering plants.

2. Insects go to flowers to gather nectar. Incidentally they transfer pollen from the stamens of one flower to the pistil of the next. While some plants (grasses, most trees) depend on the wind for transportation of their pollen, and while humming-birds also carry pollen, the most important pollen-bearers are bees, wasps, long-tongued moths, flies, and some other insects.

3. Many flowers produce good enough seed with self-pollination, but numerous flowering plants (red clover, blueberry, many brilliant flowers) form few seeds without cross-pollination.

4. Many insect structures are adaptations by means of which the insect secures nectar and transfers pollen. The sucking mouths of bees, with the trowel-shaped jaws that are used in shovelling pollen; the slender, tube-like tongues of some butterflies and moths; the hairs on the bodies of many bees; and the combs and pollen baskets on the legs of worker honeybees are other adaptations. Most insects have a highly developed sense of smell, and some possess an ability to distinguish color and have color preferences. Each insect restricts itself to one species or to a few species of flowers on a single trip. These are all aids to the cross-pollination of the flowers.

5. Some flowers depend on single species of insects to accomplish cross-pollination. Each species of yucca depends on a single species of yucca moth. The Smyrna fig depends upon a tiny, parasitic wasp.

6. Flower adaptations, by means of which pollinating insects are attracted to the flowers, include the colors, perhaps some of the colored markings, the light colors of night-blooming flowers, the massing of tiny flowers into composite heads, the united petals, the odors, the devices for keeping out ants, and such special structures as are to be found in the milkweeds, laurels, horsebalm, and lady-slippers.

7. Neither the bee nor the flower deliberately plans coöperation with the other. These structures, devices, and behaviors are adaptations as useful but not more conscious than the finger-nails that protect our finger tips or the hair that keeps a dog warm.

8. Nevertheless, each party is so dependent upon the relation, that (so the geologic record shows us) the pollinating insects did not come into existence before there were higher flowering plants, and the higher flowering plants did not appear until the pollinating insects were developed. The two groups developed at the same time, and each can continue to exist only as long as the other continues to prosper.

DEFINE

Nectar
Nectary
Pollination
Self-pollination
Cross-pollination

PROBLEMS

1. Make a list of all the wind-pollinated plants that you might find growing in your town.
2. Make a list of flowering plants, other than composites, which have small flowers borne in dense clusters.
3. Examine some one kind of wild flower. How many adaptations does it show for accomplishing cross-pollination by insects?
4. How are cultivated flowers pollinated? Make a list of the cultivated flowers whose method of pollination you can explain.
5. How many different kinds of insects can you name among those you have actually seen visiting flowers?
6. How many flowers do you know among those visited by humming-birds?
7. How is the humming-bird adapted for visiting flowers and accomplishing pollination?
8. How many food crops do you know that are pollinated chiefly by insects?
9. How many of the weeds that you might find in a vacant city lot are interesting because of their methods of pollination? Do some exploring before you finish your answer.
10. Make a list of insects that are especially important in connection with cross-pollination.
11. As far as the flower is concerned, what advantages and disadvantages are there in insect pollination in comparison with wind pollination? Discuss carefully.
12. Gardeners very often provide for the multiplication of plants without cross-pollination. In what ways? And why do they do it?

CHAPTER XXXVI

FRESH-WATER BIOLOGY

Think of water, spreading sheets of lakes and ponds, miles and miles of streams, meandering brooks and tumbling torrents, each with its peculiar attractions! The biologist associates such places with teeming, abundant life, and explores them for the unusual plants and animals they contain.

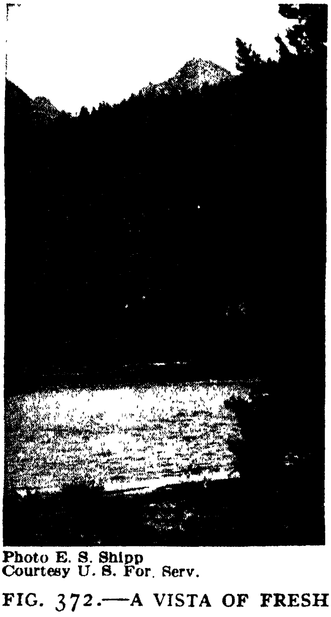


Photo E. S. Shipp
Courtesy U. S. For. Serv.

FIG. 372.—A VISTA OF FRESH WATER

Ecologic Conditions

Moisture.—However different these several places may be, they all agree in having water in them. The organisms living there are in little danger of drying up, so the animals do not need thick skins, and the plants do not need the heavy epidermal coverings which are necessary protections to land inhabitants.

Even Temperatures.—Water habitats are also favorable to organisms because water is a poor conductor of heat. It changes temperature much more slowly than the air or the earth. It is not so warm in midsummer, nor so cold in midwinter, as the surrounding country. The continual, often sudden, changes of temperature which land organisms have to endure are largely avoided by the things that live in water.

Reduced Oxygen.—Water, on the other hand, contains less oxygen than the air, and water inhabitants are hard put to it to secure this necessary gas. Many aquatic things, like the leaves of water-lilies and water skaters and whirligig beetles, have to float or swim on top of the water so they can get their oxygen directly from the air, and they cannot endure submergence for more than a short time. There are many plants that are rooted below the surfaces of shallow waters with their tops protruding. Some of the diving beetles and bugs hold bubbles of air under their front wings, and they can stay under water for longer times, but not after this supply of oxygen is exhausted.

There are other plants and animals which are able to secure enough oxygen from the supply in the water. Animals of this sort ordinarily have *gills,* which are greatly branched structures with walls so thin that oxygen can pass through directly into the animal's blood or into its air tubes. In deeper fresh waters that lack oxygen there are very few living things, and it is much of a mystery how the organisms that are there manage to accomplish respiration.

Scant Sunlight.—Sufficient sunlight for photosynthesis in plants fails to penetrate more than perhaps 30 feet into the average body of fresh water. Consequently few green things occur at greater depths.

Poisonous Gases.—Stagnant swamps and marshes sometimes develop enough poisonous gases from the decaying materials on their bottoms to prevent most organims from growing in them. Woodland pools become acid because of decaying leaves that fall in them, and they receive little direct sunlight, and consequently support few green plants and few animals beyond the stray frogs that splash in now and again. Rapidly flowing waters carry destruction with them; they sweep away food materials that might accumulate in quieter places; they are often heavily laden with mud or silt; and they change temperature more quickly than lakes; so there are not a great many organisms in rapid streams and mountain brooks. Large lakes often develop waves that are also destructive to plant and animal life.

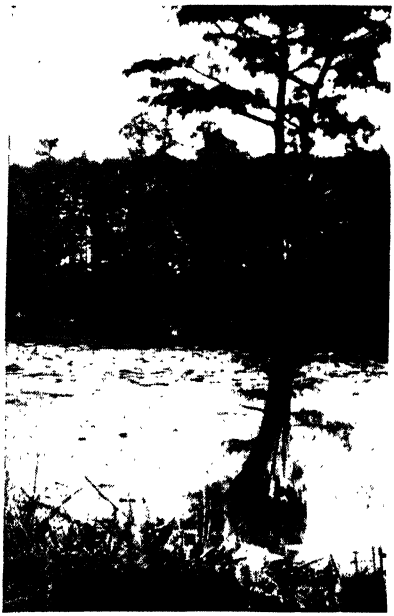


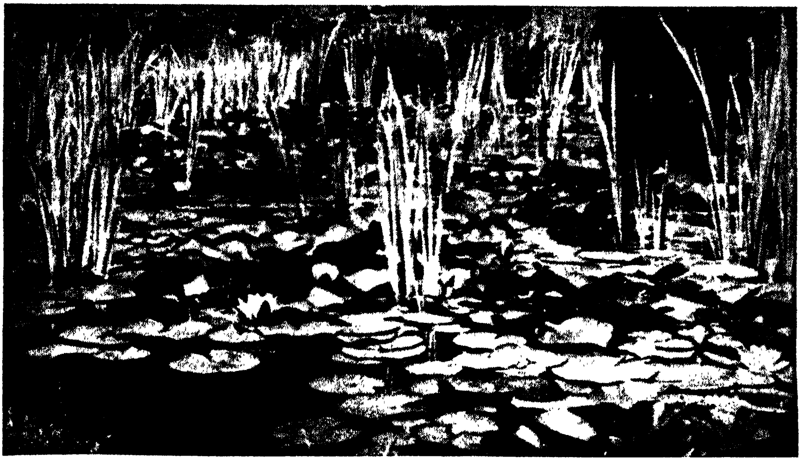
FIG. 373.—CYPRESS SWAMP IN EASTERN ARKANSAS

Just as with all other ecologic factors, extreme conditions in fresh waters largely limit the kinds of life that can occur there. A stream that ever dries up is about as good as no stream at all, as far as living things are concerned. Very shallow streams and ponds may change temperature so rapidly and freeze so solidly that their inhabitants are few. Oil and poisonous chemicals dumped from a factory into a stream, even though this happens only once in many months, may clear the stream of living things for years at a time.

These are among the ecologic conditions that determine what plants and animals may live in our fresh waters.

Fresh-Water Organisms

Plants.—Among the plants of shallow waters, there are cattails, bulrushes, arrowheads, and pickerel weeds, all of them with their heads protruding into the air. Sometimes red maple, willow, cypress, and larch trees can endure having their roots drowned. In very acid bogs, such as are common in the North, there may be found peat mosses, cranberries, cotton grasses, pitcher-plants, orchids, blueberry bushes, and related things, all of them also growing above the water to secure their oxygen. By leaning upon one another, such plants may form solid masses that float about on the surfaces of quiet lakes; and it may be possible, although dangerous, for a man to walk on such a floating bog with ten or twenty feet of water beneath.



Courtesy A. H. Wright and Carnegie Institution

FIG. 374.—SOME PLANTS OF THE SHALLOW WATERS

The leaves of many water plants are adapted to the particular depths in which they occur. The plants called water-weeds have leaves which are long and ribbon-like when they grow where waves and currents may affect them, and thus they can bend without tearing; but the same species have finely cut and fern-like leaves when they grow in protected places. The arrowheads have broad leaves when they are least submerged, and slender, narrow leaves when they are located farther offshore; and if the level of the pond changes the plant may develop new kinds of leaves in the very same season. Bladderworts bear grass-like leaves near the surface of the water, but finely cut leaves on the same stems when they extend down into deeper and quieter waters.

Many aquatic plants have peculiar tissues which contain air spaces, or special air-bladders to aid them in floating.

The broadened, flattened, more or less circular leaves of water-lilies and pondweeds float on the surfaces of even deeper lakes, for they have slimy, mucilage-like coatings on them that reduce their chances of being torn by the water.

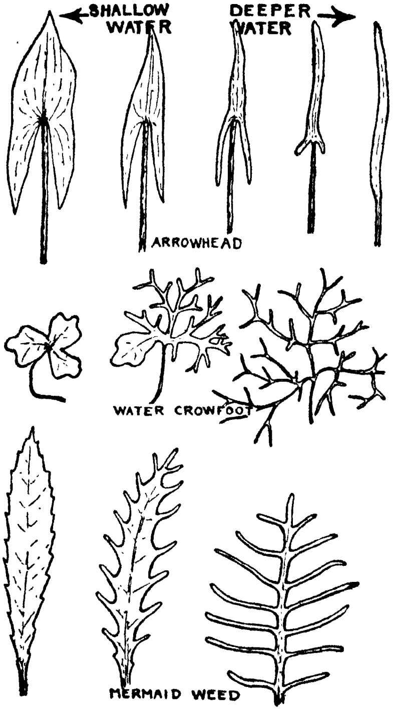


FIG. 375.—EFFECT OF WATER DEPTH ON LEAF FORM

Everywhere in fresh waters there are algæ, representatives of many species. These plants are usually microscopic and inconspicuous as individuals, but they often tinge the waters red or greenish in color, and may form scums that float, or matted tangles of plant fibers that mass beneath the surfaces.

Animals.—Most of the animals of fresh waters are very small things including protozoa, roundworms, tiny crustacea, and small insect larvæ. The pasture pool in which the small boy swims may consist in no small part of microscopic plant and animal life. Our drinking water usually contains such things. In the ponds and quieter lakes, these unseen organisms float everywhere near the surface.

This microscopic plant and animal life of fresh waters is spoken of as a *plankton.* The plankton is the main food supply of the higher aquatic animals. Few fish, for instance, can live in places that are free of a plankton.

Courtesy Nature Magazine

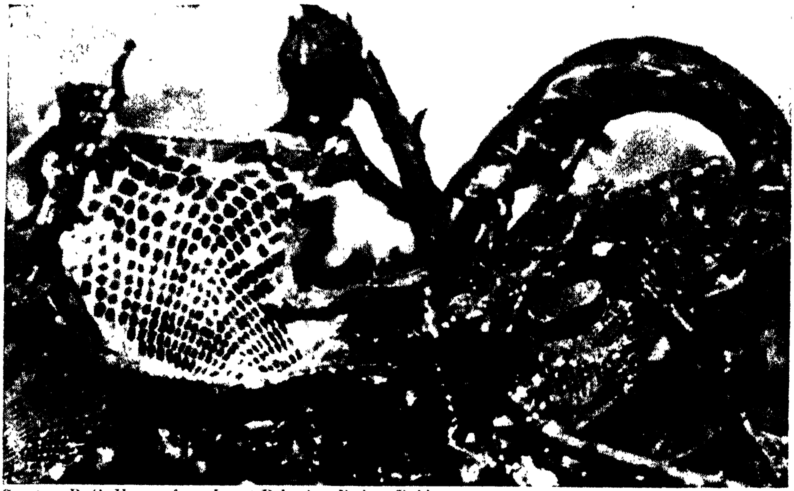
FIG. 376.—DRAGONFLY ADULT

Courtesy Nature Magazine

FIG. 377.—THE YOUNG DRAGONFLY
The cup-shaped mouth-parts carry the food back to the mouth.

Flatworms, leeches, crayfish (crawfish), and many insect larvæ are aquatic things that have their bodies flattened so they may crawl under stones for protection in rapid streams.

Insect larvæ in general are common under-water inhabitants. There are mosquito, dragonfly, stonefly, Mayfly, casefly, midge, and black fly larvæ. Each kind has its peculiar ways and is worth watching, alive in its native habitat or in the aquarium at home. Watch the wriggling larvæ of a **mosquito** come to the surface to stick its elongated breathing tube out of the stagnant waters. Examine the way the **black fly** larva uses the hooks on its head to hold onto the rocks, in streams that are so turbulent that the insects never lack a supply of oxygen.



Courtesy P. G. Howes, from Insect Behavior, Badger Publ.

FIG. 378.—THE FISHERMAN CASEFLY

The larva is to the right; one of its silken nets for collecting food is shown to the left.

See the young **dragonfly**, with its peculiar, cup-with-a-handle arrangement on its chin, snatch live insect food and shovel it unerringly into the waiting mouth. See those remarkable **casefly** castles, built of tiny sand grains or pebbles held together with silk, made to protect the bodies of the young insects while their hungry jaws sit out-of-doors, ready to eat whatever the stream brings along. Or see those fisherman caseflies that build silken nets on the bottoms of swift brooks, and at the bases of cataracts and waterfalls, and that spend their days travelling between their several nets, collecting the bits of plants or stray insect remains that are swept into them. These, and many other delightful performances, you may see if you will explore in appropriate places.

Mussels (fresh-water clams) are abundant in many rivers. The quite helpless, young stages of many species become attached to the gills or fins of fish, and there they may live for some weeks or even months as parasites, until they transform into mature molluscs. The fish carry the mussels upstream and downstream, thus becoming the chief agents of distribution of their invertebrate guests.

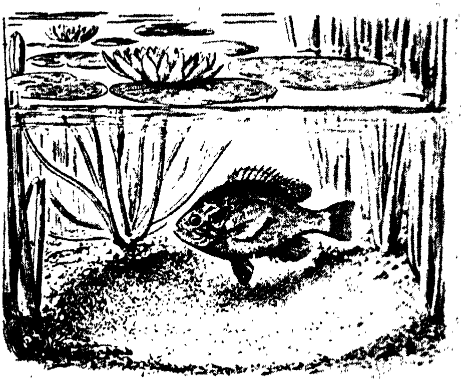
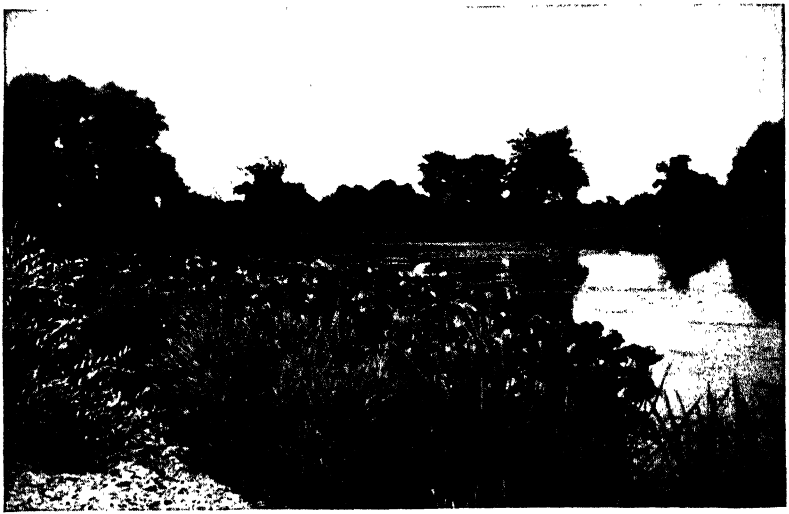

From Gill. Courtesy Smithsonian Inst.

FIG. 379.—A SUNFISH NEST

Snails occur in all fresh waters, as great tangles of their narrow tracks left on muddy bottoms will testify.

The **fish** are probably better known to you than the other inhabitants of fresh waters. But have you seen the catfish, the sunfish, the black bass, or some of the sticklebacks making their nests by hollowing out depressions in the mud, or by sweeping up stones and sticks and other debris? And have you watched them as they guard their eggs or the young in those nests?

Frogs, toads, salamanders, water snakes, ducks, grebes, loons, gulls, sandpipers, otters, mink, and beaver may live for part of the time on or above dry land, but they depend upon aquatic places for much of their food and for the materials out of which their homes are made; and these creatures must also be counted among the inhabitants of our fresh waters.



Courtesy C. H. Kennedy, Ohio State Univ.

FIG. 380.—POND ECOLOGY, NORTHERN OHIO

Showing surface plants, shallow-water plants, wet shore plants, shrubs, and trees.

It would be very difficult to gain a knowledge of any of these plants and animals which we have listed without considering the peculiar environments in which they live.

Lake Biology

A *lake* is just a body of water larger than a pond, but because of its size and depth it may have a peculiar effect upon the distribution of the living things in it. The study of lakes and the organisms that live in them is called *limnology.*

Most of the live things in a lake occur in the shallow places near shore. They may be the same species as are found in other shallow waters like marshes and swamps. If a lake has shores which are rocky or steep, they will support fewer shallow-water organisms.

In the depths of a lake there are few plants or animals of any sort. But everywhere in the surface waters there are plankton organisms, and some larger fish swim far out from shore.

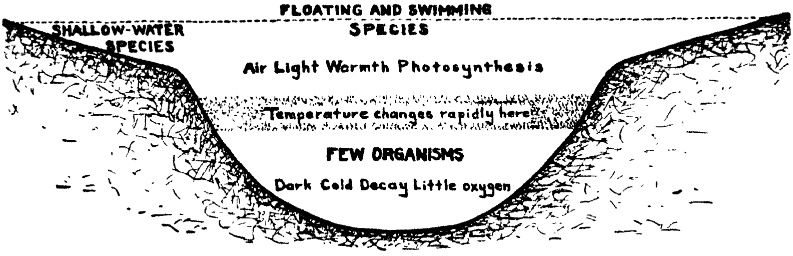

FLOATING AND SWIMMING SPECIES
SHALLOW-WATER SPECIES
Air Light Warmth Photosynthesis
Temperature changes rapidly here
FEW ORGANISMS
Dark Cold Decay Little oxygen

FIG. 381.—A LAKE STRATIFIED
Distribution of life in the lake in the summer.

Lake Stratification.—There is an interesting chain of events which determines how deep living things may go in a lake. It begins with sunlight, the heating effect of which penetrates only a few feet into the waters of a lake. These surface waters become uniformly warm because they are continually mixed by the wind down to say forty feet in the average lake of moderate size (down thirteen to one hundred feet in various lakes). Below that point the temperature becomes very low, reaching 39°F. (a little above freezing) in the deeper parts of many lakes, even during hot summers. The waters separate into layers; the lake *stratifies,* we say.

But warm waters are lighter in weight, less dense, than cooler waters. It is relatively difficult to mix waters of different densities. And so, throughout the summer, no ordinary force is able to mix the warmer, less dense surface waters with the cooler, more dense waters beneath. No wind, no gale that blows, can do more in the summer than stir the upper layers of the waters.

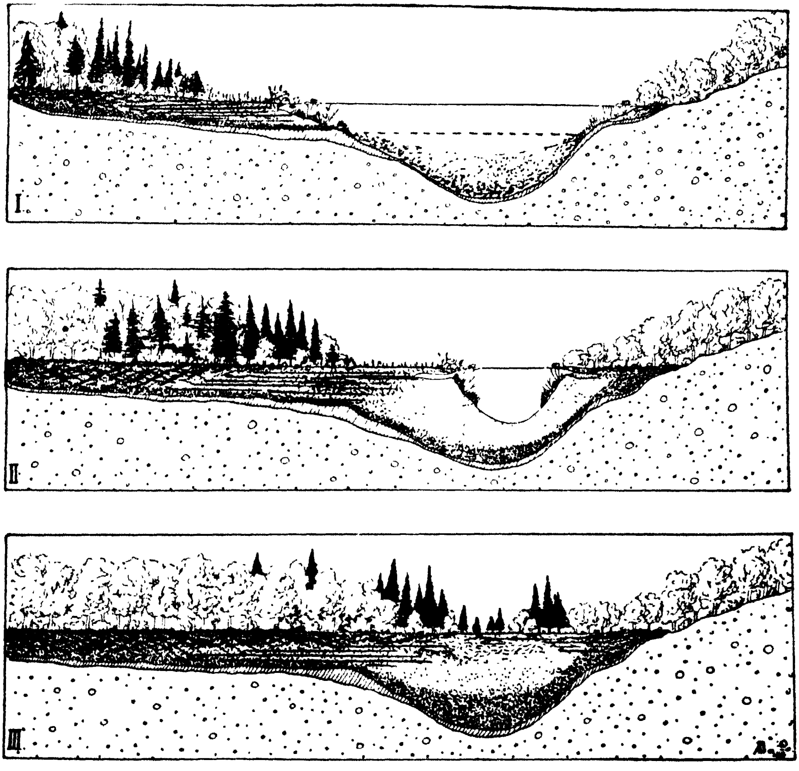
Oxygen from the air is continually mixed into these upper levels, but lower down the oxygen supply is not renewed. In the cooler and larger lakes farther north, some oxygen may remain in the depths all summer, but in many lakes what there was of the gas in the deeper waters at the beginning of the season is soon used up by the organisms, and they have to leave the region.

The decay of organic matter at the bottom of the lake, and of the dead organisms that drop down from the upper levels, releases considerable carbon dioxide which remains bottled up in the deeper water during the whole summer. Because of the low temperatures, the lack of oxygen, and the abundance of carbon dioxide, plants and animals of most sorts simply cannot exist in the deeper waters of many lakes.

After the summer, the surface waters cool. Finally, some day late in the autumn, they approach in temperature and density the waters that are below. Then a light breeze, just a breath of air, may accomplish what the midsummer gale was unable to do, stirring the lake from top to bottom, turning it over and over, releasing all the imprisoned gases, and mixing all the water with oxygen. If our drinking water comes from an open reservoir of any depth, we may notice that it has an unpleasant taste at that season because of the gases that have been released from the lower waters.

In the lake, conditions are now livable at any depth. They remain so through the winter and into the spring, until the warming sun once again causes the waters to stratify. It is a remarkable situation, illustrating how closely organisms are dependent upon their environment!

Filling of Lakes.—The shores of lakes are continually changing. They are forever being eaten away by wave action. They are continually being extended by mud and debris brought in by streams. They continually push out into the lake because the shallow-water plants gather sediments about their roots, and in a few years bring solid ground out above the water level. If the shores of a lake are steep, with few shallow-water plants, the lake may remain indefinitely; but if the shores slope gradually and bear many plants, the whole body of water may disappear in a century or two. A surprising number of our lakes are changing into deep-water swamps, shallower swamps, bogs, and wet meadows, and finally becoming firm land with only small brooks remaining to drain the areas. During the successive changes in a lake, the list of inhabitants must change, until finally all truly fresh-water forms disappear from the region.



Courtesy A. P. Dacknowski

FIG. 382.—THREE STAGES IN THE FILLING OF A LAKE

Conservation

Values of Fresh Waters.—Fresh waters are of value to us because of the pleasure they provide. It is an attractive landscape that is broken by a vista of some water, the windings of a broad river, some grassy-banked brook, a tumbling mountain stream, the shimmering surface of a pond, or the great stretches and white-capped waves of a lake. To such places we may go for cool in the summer, for swimming and rowing, for canoeing and sailing, for rest and dreaming, for fishing, for camping. Folks need such healthful recreations. We live best when we have them.

Our larger rivers are also useful for navigation. The water power in both small and large streams is of increasing importance in the turning of machinery and the production of electricity. Natural waters furnish the agriculture of adjacent lands with their only supply of moisture during rainless seasons. Irrigation waters must come from streams and lakes. The fish of fresh waters provide considerable human food. Fresh-water mussel shells are turned into pearl articles worth several millions of dollars each year. The drinking waters of many of our towns and cities come from lakes and ponds and streams.

So, of course, we want the fresh waters of America saved. To serve us in all possible ways, they must be conserved, usually with their natural ecologic conditions. Sometimes changes will have to be made. Many marshes will have to be drained to prevent mosquitoes from breeding. Some drainage will be necessary to provide dry ground for agriculture and building. Fish will be killed for sport and for food. Some lakes and rivers will have to be dredged to keep them in existence. But, in general, the fresh waters should be preserved with as few changes as possible.

Enemies of Conservation.—However, such conservation has its enemies. Lumber interests strip the trees from the hillsides where streams originate, causing floods and droughts in the country. Owners are so anxious to uncover lands for agriculture that they dig drainage ditches too deep; the level of the water in the soil of all the surrounding country consequently falls too far below the surface, and it proves impossible to practice the very agriculture it was intended to better.

Copyright Asahel Curtis, Seattle

FIG. 383.—MAY WE FOREVER CONSERVE SUCH WATERS AS THESE
Along the Gallatin, Montana.

Some fishermen use unsportsman-like nets and dynamite, and pull out too many fish, take female fish ready to lay their eggs, and otherwise disregard the state fish and game laws. Manufacturing plants put wastes, often very poisonous chemicals, into ponds and streams, and large cities dump too much sewage into small streams, killing all plant and animal life for miles and miles along the waterways. Oils dumped into water never mix well, and are responsible for the ruin of many waters.

Each of us may aid in remedying these practices. On fishing expeditions, we will be good sports. We ourselves will not pollute streams, especially small streams which someone farther along may be using for drinking purposes. We will be interested in seeing established and maintained such laws and public sentiments as will conserve for this and for coming generations those interesting formations called our fresh waters.

SUMMARY

1. The peculiar ecologic conditions in fresh-water habitats account for the interesting plants and animals which we find there. Organisms living in water are in little danger of drying up. Temperatures change more slowly in water habitats. Oxygen is not always abundant in water, and water plants and animals usually have special structures by which they secure oxygen. Sunlight is insufficient for photosynthesis at any depth. Poisonous gases are often found in deeper waters and in swamps and marshes.

2. Water-inhabiting plants protrude above the surface, float, or are submerged in shallower waters. Leaves in still waters may be broad; the leaves of the same plants in more active waters may be ribbon-like or finely dissected. Many water plants have floats, or other devices for keeping the leaves at or near the surface.

3. Water-inhabiting animals are mostly small. Microscopic plankton organisms (protozoa, small crustacea, microscopic worms, etc.) are everywhere, especially near the surface. Some water animals have flattened bodies and live under stones. Insect larvæ are abundant, many of them with such interesting ways that you will want to watch them in the stream or in the aquarium indoors. Mussels and snails are sometimes common. Fish are the most abundant vertebrates, but many other vertebrates (frogs, toads, snakes, birds, beaver, etc.) are regularly found near if not in the water.

4. A lake, because of its size, provides an aquatic environment which has an especial influence on the life in it. In the summer, the warmer upper layers of a deep lake do not mix with the colder, deeper waters. The lake stratifies. In the deeper waters the oxygen is soon used up, and practically no plants and animals can live there then. In the fall when the surface and deeper waters become nearly the same temperature the waters mix and the organisms become more widely distributed again.

5. Lakes with steep sides are fairly permanent, but lakes with more sloping sides gradually become filled with debris that gathers about the roots of the shallow-water plants. Finally the whole body of water may be replaced with dry land.

6. Our fresh waters are invaluable for recreation, navigation, water power, drinking and agricultural water supplies, and as sources of human foods. To obtain all these benefits from our fresh waters, they need to be preserved as nearly as possible in their natural forms.

7. Conservation of our fresh waters requires forest conservation on the watersheds, control of drainage projects, regulation of fishing, and prevention of pollution by manufacturing wastes or by sewage (especially from cities). Oils dumped into streams are especially serious sources of pollution. Our fresh waters will be preserved whenever our people understand their interest and value.

DEFINE

Aquatic
Gills
Floating bog
Plankton
Limnology
Lake stratification
Lake turn-over
Conservation

PROBLEMS

1. How many distinct kinds of natural fresh waters have you ever seen?

2. What pleasures have you had from fresh waters? Describe some one experience.

3. What peculiar plants and animals have you ever seen living in fresh waters? Why haven't you noticed more of them?

4. Clearly explain how the sun's heat, water density, stratification, oxygen, and carbon dioxide content control the distribution of lake organisms in the summer, and why they are not so important during the rest of the year.

5. What foods have you ever used that are dependent upon the existence of some body of fresh water? Are you sure you have listed them all?

6. Is a limnologist a botanist, a zoologist, a biologist, or an ecologist? Discuss.

7. If a jar of water containing aquatic plants is placed in warm sunshine, small bubbles of some gas will rise to the surface of the water. There are two entirely different kinds of bubbles. What are they, and from where does each kind come?

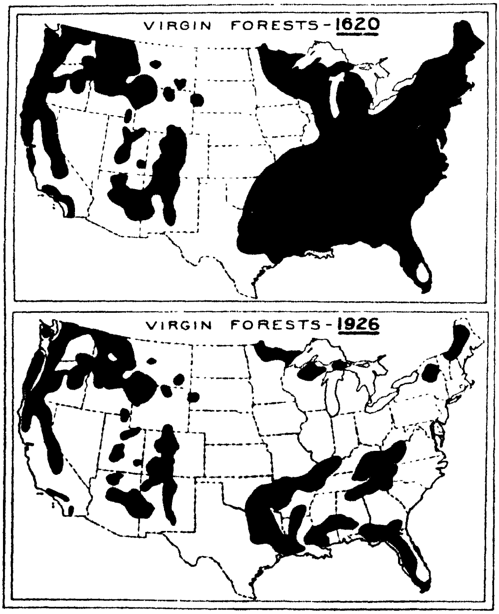
8. In a small aquarium the water will become "bad" and fish in it will die unless the water is changed. What organisms must be included in an aquarium in order to keep it "balanced," so animals can live in it without having the water changed?

CHAPTER XXXVII

PROBLEMS IN CONSERVATION

When the first Europeans reached this continent, they found forests which stretched halfway across the land, ready to supply building material and fuel as man needed them. The decaying branches and leaves of these forests had built soils wonderfully suited to the growing of human foods.

In the Middle West and on the plains further west there were grasslands which supported vast herds of bison, and could similarly support great herds of cattle. In the moister part of the prairies, the decaying sod had helped make a black soil even richer than the soil of the eastern forests.



Courtesy U. S. Forest Service

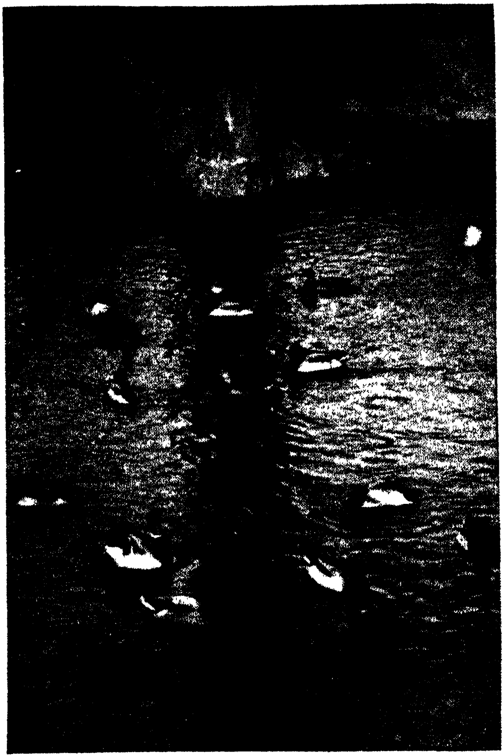
FIG. 384.—HOW WE HAVE USED OUR FOREST RESOURCES

There were fish, shellfish, game birds, and wild mammals as ready food for human consumption.

There were waterways along which pioneer migration and early commerce could proceed even to the remote interior of the land.

The mineral resources included iron, lead, copper, zinc, silver, gold, coal, and petroleum in such vast quantities as few other parts of the earth possessed.

It was a varied land with forests, grasslands, and deserts, mountains and swamps, mountain glaciers, and near tropics. It had birds, mammals, flowers, and trees in unmatched variety for scientific study, for out-of-door recreation, for the enjoyment of all who know that life is worth the living.



Courtesy Ind. State Conservation Dept.

FIG. 385.—OUR DUCKS NEED WISE PROTECTION

Wasting Natural Resources

These were the natural resources on which the nation would have to depend for the many centuries to come. But already the stores have been seriously reduced; and much of what remains is now privately owned; so the people as a whole have difficulty in enjoying their benefits.

Our natural resources were wasted partly because forests interfered with the use of the land for fields, pastures, homes, and highways. The resources were cheap as long as there was an abundance. It paid to cut the best timber, to mine the most accessible coal; but it did not pay to save the rest.

When there were very few people in the country, the resources seemed much greater than today. Indeed, many people believed that the natural resources were so great that they would last forever.

It is also true that the desire for personal profit was stronger than the interest in the public welfare. This is a selfish viewpoint, but, unfortunate as it may be, such an interest in one's own personal welfare is as natural as breathing or eating. It takes wisdom, intelligence, and group (governmental) action to consider the good of the nation as a whole.

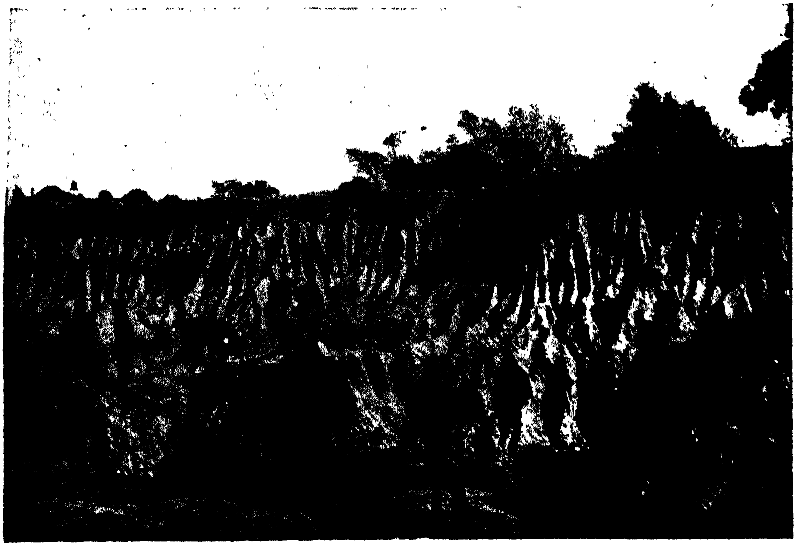


Photo by W. R. Mattoon. Courtesy U. S. Forest Service

FIG. 386.—A RESULT OF REMOVING THE FOREST COVER

Fortunately, it is not yet too late to repair much of the damage that has been done. We have already pointed out (Chapter XXXII) that wiser cutting of the forests would easily double our income from them. Much land better adapted to trees than to agricultural crops is available for replanting. Our mineral resources are still enough to spread over many centuries if we mine and use them carefully.

We apply the term **conservation** to this wise use of natural resources.

Within the last hundred years the population of the United States has multiplied nearly six times. But now immigration has largely stopped, and the average size of families is sharply decreasing. Experts believe that by 1950 our population will stop increasing, and after that may even become smaller. Such a fixed or smaller population will make it easier to work out a program of conservation.

Kinds of Conservation

There are a number of our resources which need conservation.

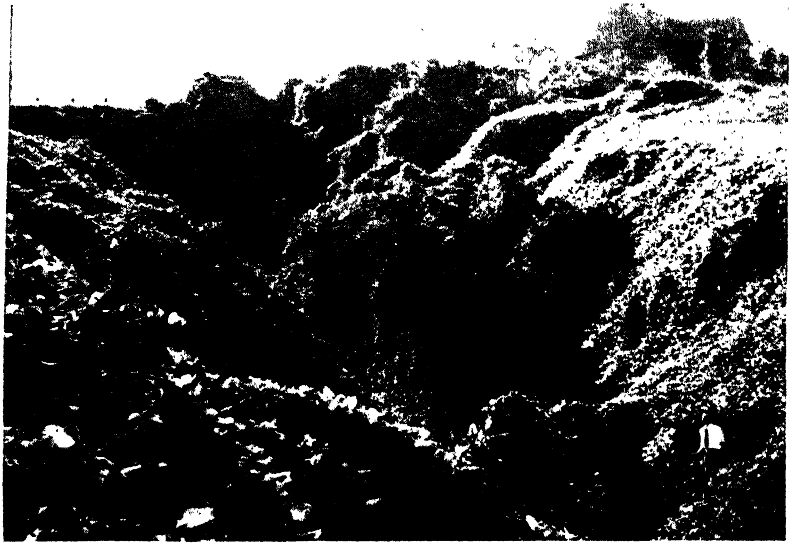
Forest Conservation.—The protection of forests was one of the first forms of conservation, and it remains one of the most important. In an earlier chapter (XXXII) we have discussed the ecologic importance of forests and mentioned some of the problems in forest conservation. Go back to that chapter and make a list of the things that should be done if we are to make a wise use of our forests.

Soil Conservation.—On farms in many parts of the country a large part of the plant foods has been taken from the soil. In many cases such land should be replanted with forests that will build up new soils. Everywhere, fertilizers should be used to replace plant foods removed by farm and garden crops.

Even more serious is the actual washing away of the soil where the natural protective cover of forests or grass turf has been removed, or where the land has been unwisely cultivated. The clay soils of the South are especially liable to such deep erosion. This is one of the great wastes of our resources. A federal survey shows that more than 125,000,000 acres of former farm land, an area more than twice the size of the state of Indiana, is now abandoned because of soil erosion. Fortunately, every farmer and everyone who works ground can do something to prevent such damage. Here is a very practical way for some of us to contribute to conservation.

Soil erosion may be controlled by planting forests or heavy sod covers, and by building log and brush dams in gullies.

Grazing by cattle, sheep, goats, and other animals should be controlled so that young trees are not damaged and sod enough is left in the grasslands to hold the soil together.



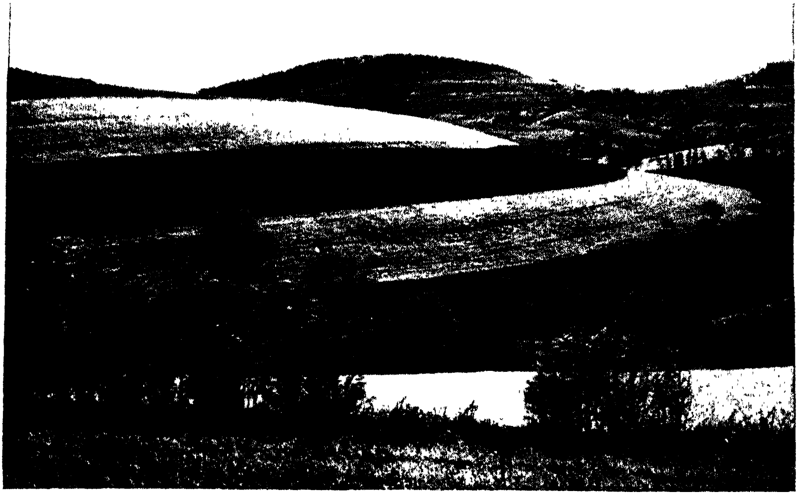
Courtesy U. S. Soil Conserv. Serv.

FIG. 387.—ONE WAY OF CONTROLLING SOIL EROSION

A two-year growth of kudzu vine, a very fast-growing plant of the pea family, native of eastern Asia. Find the man in the picture. Further erosion on this Georgia farm has been effectively stopped.

Ploughing thin and fine soils in arid areas may make them so fine and dry that winds pick them up and blow them over half of the continent. This problem has become particularly serious in recent years, largely because of the cultivation of parts of the high plains where extensive cultivation should never have been encouraged.

Bands of close-growing plants which stop run-off can be planted between such "clean-tilled" crops as cotton, corn, and tobacco. This is known as strip-cropping. As rain waters drain off of the clean-tilled land, they are caught in the denser crops of grass, sweet clover, or small grains; the dissolved soil is deposited there; and much of the water is absorbed.



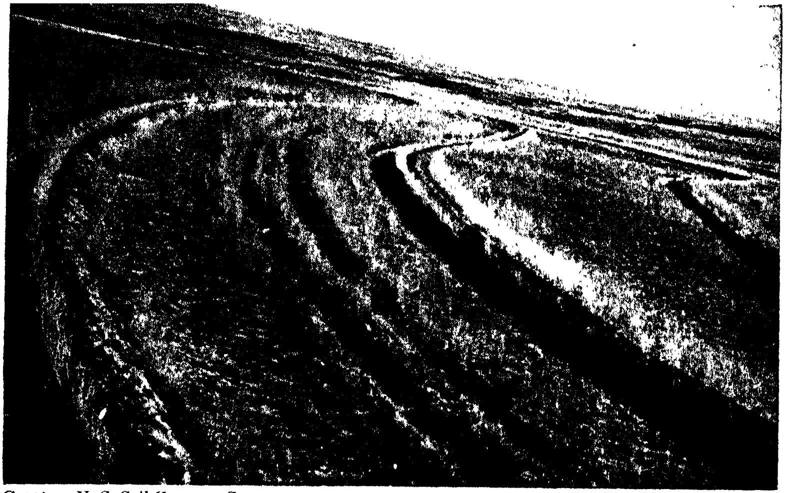
Courtesy U. S. Soil Conserv. Serv.

FIG. 388.—STRIP-CROPPING
Explain what the picture shows.

Contour plowing is a system of making furrows across the side of a sloping piece of land so that drainage is caught there instead of rushing down the hillside to wash away the soil.

Still other systems of plowing, machines for scooping out holes to catch the water, the building of terraces, and other means have been developed and should be extensively used to reduce the washing away of farm soils.

Flood Control.—The great rivers of this country, from Maine to California, have brought disaster time and again to miles of farmlands and to some of the largest cities of the country. There is every evidence that floods raged through these river valleys long before white man arrived; and in spite of all that man may do they will come again whenever a "record-breaking" rainfall or melting snows dump more moisture into any valley than the soil can possibly absorb or the stream carry away in its inner channel. Such big floods cannot be prevented or even lessened to any extent by anything that man can do. Man can, however, reduce the frequency of disaster from ordinary floods by:



Courtesy U. S. Soil Conserv. Serv.

FIG. 389.—CONTOUR PLOWING

What is contour plowing? What does this photograph show?

1. Keeping the headwaters and main valleys of these streams forested as far as possible.
2. Building levees to confine the main streams; and building dams on the headwater streams to control the amount of water contributed to the main streams.
3. Building spillways and floodways which allow a flooded river to dump some of its load into back swamp areas, if the

flood is too great to be retained by the levees. Such overflows may empty through other rivers or through the main stream at some later time.

4. Removing cities, towns, and highways to higher land away from streams. This is the surest means of preventing damage by both ordinary and great floods. Some smaller towns are already doing this. But people owning land in the valleys cannot sell it for much, and nearby higher land is expensive; so the larger cities find it very difficult to move any large number of their people. Nevertheless, in time we expect to see this sort of wiser adjustment to floods.

Courtesy U. S. Bur. of Reclamation

FIG. 390.—WISE IRRIGATION HAS TURNED ALKALI DESERTS INTO FERTILE FARMLANDS: IDAHO

Water Supply, Water Power, Waterways.—The streams and lakes and the underground waters of the country provide most of our drinking supplies, irrigation waters, power for turning mills and for generating electricity, and channels for travel.

Pollution of lakes and streams by sewage from cities and from manufacturing establishments is a menace to all the plants and animals that live in the water, and it interferes with the use of the water by man for drinking purposes (see Chapter XXXVI).

The use of water for irrigation has turned portions of the western plains and deserts into fertile farmlands. But irrigation is sometimes more expensive than the crops are worth, and irrigation waters sometimes deposit harmful alkalin salts on the land.

FIG. 391.—WATER SUPPLIES, WATER POWER, RECREATION

This stream, in northeastern Pennsylvania, is on the estate of Gifford Pinchot, first chief of the U. S. Forest Service.

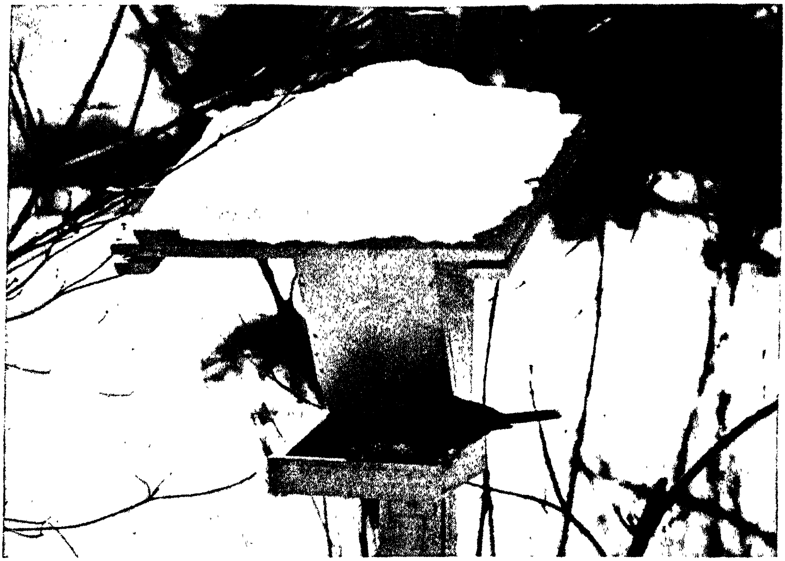
For purposes of transportation, the most valuable of our fresh waters are the Great Lakes and the lower portions of such rivers as the Mississippi. The smaller streams and many built canals were invaluable in pioneer days, but the railroads and now the highways provide cheaper and more direct transportation. Within recent years, against the advice of many engineers and most students of conservation, the national government has spent over a billion and a half dollars to deepen river channels and to build new canals. The savings, unfortunately, nowhere equal the costs.

For recreation, these fresh waters provide boating, swimming, fine places for camping and for summer homes, and endlessly interesting places to explore (see Chapter XXXVI). For such use, the streams and lakes need preservation in as natural a state as is still possible. Drainage should be controlled. Portions of the shores should be set aside as state or national parks so that the public will not be shut out by private property owners. In many regions, especially in the Eastern United States, lake shores and even the ocean beaches are so largely controlled by private owners that only a few people are ever able to enjoy them. There is now underway a plan for a great National Park to be located on the Atlantic beaches. We need other parks on the New England coast, and on the inland lakes of New England and the Middle West.

Recreation.—We are finally realizing that recreation is a fundamental part of life, and that the out-of-doors is a splendid place in which to re-create one's soul. The public is turning, in increasing numbers, to the National Parks and to the many parks under state control. Within recent years the National Forests and State Forests have been opened for increased public use. These places are among the great assets which we, as a nation, possess.

Conservation of Wildlife.—The protection of beneficial birds, mammals, and other animals is good ecology, as we have already learned. On the other hand, hunting and fishing for food and for sport are age-old occupations and recreations of man; and as long as they cause no serious ecologic disturbance they are legitimate ways of using natural resources. But the near extermination of most of our larger mammals, including whales and other large animals of the sea, and the similar destruction of many of our game birds, fish, lobsters, and oysters is the result of hunting and fishing far beyond the limits set by good ecology.

There are now National and State laws limiting the kinds and number of fish, mammals, and birds that can be legally killed, and requiring the protection of rare species, of young individuals, and of breeding females. Fish hatcheries are raising millions of young fish for re-stocking streams. But state fish and game commissions and even the bureaus of the national government have been controlled largely by sportsmen and by manufacturers of rifles, powder, and fishing tackle. These people are sincerely interested in seeing wildlife protected and developed to a point which will allow more hunting, but the laws should more often take into account the general ecologic importance of such animals and not merely their value as game.



Courtesy Esther Heacock, from Frontiers, Phila.

FIG. 392.—A PRACTICAL WAY FOR ALL OF US TO AID IN CONSERVATION

Cardinal at a winter feeding station.

Some control of such harmful animals as ground squirrels, coyotes, and wild cats is often necessary to correct the damage done by man as he enters the ecologic picture. But if we attempt to correct our mistakes by exterminating these animals, we are sure to tip the balance in some other direction. You will recall that when the predaceous mammals on the Kaibab were destroyed, the deer so prospered that they destroyed the plant food supply in the region and then starved. Similarly in parts of the East deer have become pests because of the destruction of their predatory enemies. Nevertheless the federal Bureau of Biological Survey has been trying to exterminate rodents (prairie dogs, ground squirrels, etc.), and predaceous animals like the coyote. There is no question that these animals have done great damage to cattlemen and ranchmen. But we have already seen (Chapter XXXI) that the extermination of any pest is practically impossible; and biologists are more inclined to depend upon the natural enemies of pests (upon biologic control).

From Bruce Horsfall and Nature Magazine

FIG. 393.—ANOTHER SUGGESTION FOR AN EVERYDAY CONTRIBUTION TO CONSERVATION

Conservation of Mineral Resources.—Living crops, and even such things as soils and fertilizers which are influenced directly by the plants and animals in an area, may be grown and renewed. But minerals (coal, metals, oils, etc.) are not a part of the living world, and they cannot be regrown or in any way renewed after they are used up. In this biology course we shall, therefore, add nothing to what we have already said about the conservation of mineral resources.

Scientific Basis of Conservation

You see that an understanding of the ecologic significance of forests, insects, birds, and fresh-waters, and an understanding of ecologic balance are the scientific principles on which the conservation of plants and animals should be based. But in any program of wise use we are called upon to decide which of perhaps several means is the best for obtaining results. We are asked, in other words, to apply our science, and that is often very difficult to do.

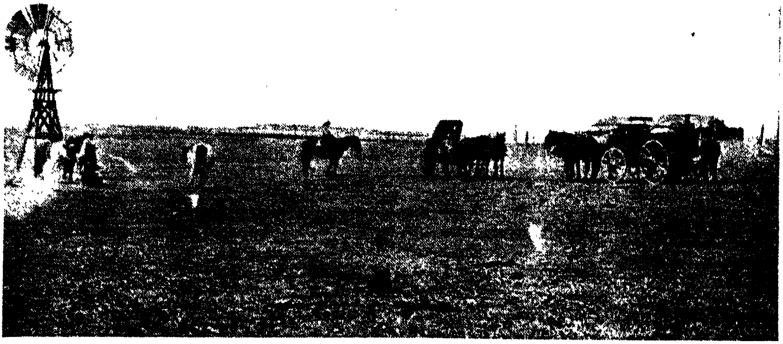


FIG. 394.—IS THIS LAND WORTH FARMING?

Can it be made to raise good crops? What happens in dry years? What should be done with such land?

For instance, extensive dry land farming in the high plains ignored the importance of the sod in binding fine and dry soils. When several years of drought turned this area into a "Dust Bowl," we learned that we had not used enough science in handling this problem.

The value of a shelter belt of planted trees in the normally treeless plains is also a debatable matter. There are some who believe that more extensive plantings, from the Dakotas to Texas, would do a great deal to break the force of wind and dust storms. But there are many who believe that planted trees have little chance of lasting in that region, that the effect of trees would not be felt for any great distance, and that we do not yet know enough of this ecologically complicated problem to succeed.

FIG. 395.—THE CONSERVATION IDEA MAY BE APPLIED TO MAN
The sciences of physiology, genetics, and biology as a whole, may contribute to the saving of such resources.

Most of the fish raised by state conservation and game commissions die soon after being planted in open streams. This is because we have not yet learned enough about the life histories of the fish and the ecologic conditions necessary for their existence.

Everywhere road crews are cutting and broadening hillside grades, as a result of which enough raw clay washes into the valley streams to spoil their beauty and destroy much of the plant and animal life in them. Other crews are building dams and walling up the sides of streams in their efforts to "preserve" them. Thousands of meandering brooks have thus been robbed of their natural beauty and ecologic usefulness.

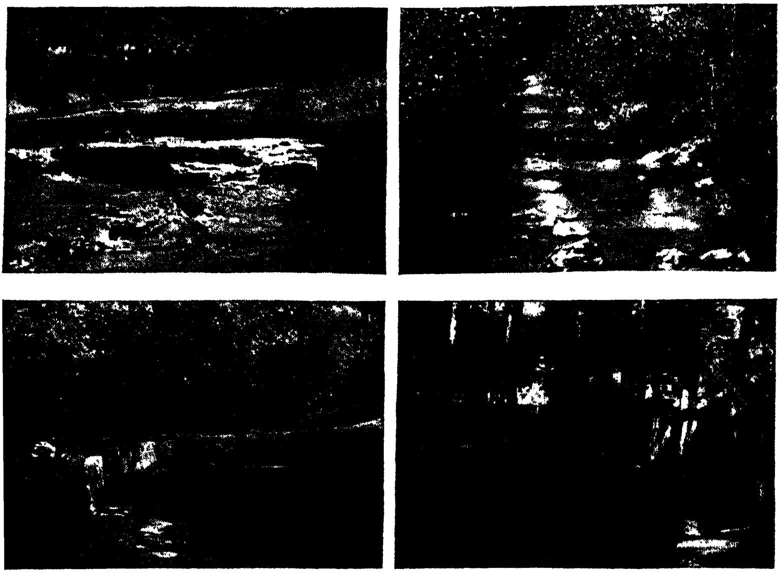


FIG. 396.—MISDIRECTED ATTEMPTS AT CONSERVATION

The original stream, in the two photos above; and the stream as rebuilt, in the two below. Which contributes more to this interesting world? What are the ecologic results? Are there instances of such work in your community? Who is responsible? What can be done to prevent such mistakes?

In the effort to replace our depleted forests, all available land should not be planted; for the birds and game (which we are, at the same time, trying to protect) require grassy, open areas and brush thickets. Moreover, much replanting is being done with conifers even in regions where no species of conifer is native; and it is improbable that the wildlife of oak and hickory forests will thrive in the dense pine forests being planted.

In order to reduce fire hazards, and in some instances in order to prevent falling leaves from washing into reservoirs, the underbrush has been cut and all surface litter has been removed from miles of forests. As a result the hillsides have washed into the very streams and reservoirs that it was intended to protect. Natural renewal of the forest from young growth has been prevented; and areas which once were refuges for birds and other wildlife have become like city parks.

One branch of the government is developing irrigation and aiding settlement in semi-arid areas; another is encouraging people to move off of "sub-marginal" lands.

One branch of the government calls on modern science to increase the amount of food that the farmer can raise on an acre. In the same year, the farmers are paid not to plant all of their land, and the government buys up parts of certain crops and destroys them.

Millions of dollars are spent each year on a bureau which develops methods of controlling such insects as the cotton boll weevil and other pests so as to increase yields. In the same year the government pays the farmers to plant part of their cottonlands to other crops in order that the price of the cotton may be raised.

No thoughtful person doubts that we should conserve our natural resources; but it is clear that a great deal of knowledge of ecology is needed before we can have a wholly successful program in conservation.

SUMMARY

1. America was rich in its original resources of forests, grasslands, food animals, waterways, and minerals.
2. Within a few generations, these resources have been seriously reduced. Much of what remains is now privately owned.
3. Fortunately, our resources are still sufficient if we use them wisely. This *wise use* of natural resources is what we call conservation.

4. Forest conservation is one of the most important forms of conservation. See Chapter XXXII.

5. Soil erosion represents one of the greatest wastes of natural resources. Everyone who works ground can contribute to soil conservation. Planting, control of grazing, preservation of thin soils in dry areas, strip cropping, contour plowing, terracing, etc., will help control soil erosion.

6. Flood damage may be reduced by forestation about headwaters, building levees, spillways and floodways, and (surest of all) by moving towns and cities to higher ground.

7. Water supplies have been discussed in Chapter XXXVI. The inland streams are of minor importance today for purposes of transportation.

8. Wildlife needs to be conserved for its ecologic importance, as well as its value to the hunter and fisherman. Animal pests are best held in check by their natural enemies.

9. The conservation of mineral resources is important, but not a matter of biology.

10. In conservation we are asked to *apply* our science, and that is often very difficult to do. We need to know a great deal about ecology before we can have a wholly successful program in conservation.

DEFINE

Natural resources
Conservation
Erosion
Strip-cropping

Contour plowing
Spillway
Floodway
Pollution

PROBLEMS

1. List all the pages in this book (outside of the present chapter) which contain material on conservation. Record the natural resource which is considered on each page.

2. It has been suggested that conservation should be a whole unit in this biology course. Here it is treated as a part of Ecology. What are the advantages and disadvantages of each arrangement?

3. What were the most important natural resources in your state when white man first arrived?

4. Which of the resources of your state are now entirely exhausted? Which badly reduced? Which are still in their original abundance?

5. What are the most important conservation problems in your own county?

6. From your travels, give cases of conservation projects (CCC work, re-forestation, dams, etc.) which you have actually seen. Be prepared to describe one case for the class.

7. Name the kinds of business, occupations, or industry which have most to do with our natural resources—their wise use, or their waste.

8. In what ways can high-school boys and girls contribute to the conservation of our forests: when they live in a city? in a suburban town? on farms?

9. Similarly, explain how boys and girls can contribute to soil conservation, when they live in cities, or towns, or on farms.

10. Explain how boys and girls can help prevent floods, when they live in cities, or towns, or on farms.

11. Explain how boys and girls can contribute to the wise use of water supplies and water power, when they live in cities, or towns, or on farms.

12. Explain what boys and girls can contribute to the conservation of wildlife, when they life in the cities, or towns, or on farms.

13. Explain what boys and girls can contribute to the conservation of our mineral resources.

14. In connection with the conservation of these several kinds of resources, what can an adult contribute that a high-school boy or girl could not contribute?

15. What forms of conservation have to be conducted by state or national governments, and cannot be well handled by an individual citizen?

16. List the means of flood control, in order of importance, with the most important at the top. Which means have been most often used? Are these the best means? Why?

17. Why do we spend vast sums for aiding water-borne traffic, but collect enormous sums from the railroads as taxation?

18. List ways in which national, state, and local governments have contributed to the use of the out-of-doors for recreation.

19. Millions of dollars have been spent as bounties for killing predatory animals. Is it worth it?

20. Most coal operators make little profit. Then how can they be expected to use the more costly means which represent good conservation? What can be done about it?

21. Is it ever justifiable to destroy good food materials? Discuss. How much of your answer is biology, and how much is something else?

22. Is it better to have everyone use all cloth until it is completely worn out, or is it better to have them buy new cloth as soon as the old is a bit used? Discuss.

23. From your own observations, or what you have heard from first-hand observers, give instances of conservation work which was of doubtful value. In each case, what should have been done to make the work scientifically sound?

ECOLOGY: REVIEW

1. Review the definitions of all words listed at the ends of Chapters XXIX through XXXVII.
2. Review all of the summaries at the ends of those same chapters.
3. Review the problems given at the ends of those chapters.
4. Explain what is meant by each of the following statements. These are the important principles in that part of Ecology which you have studied.

CHAPTER XXIX. **Ecologic Relations.**—The biology of every organism depends upon the environment in which that organism lives. The ecologist studies these relations between organisms and their environments.

There are many types of ecologic relations, resulting in the formation of chains and webs of relations too complicated for easy understanding.

An ecologic balance results when all the organisms in any chain are prosperous, and when no one is too prosperous. Balanced conditions are good for all the organisms involved.

CHAPTER XXX. **Epidemics.**—Epidemics are the result of an upset balance. For a time one organism prospers unduly. Epidemic conditions are bad for all organisms involved, even for the one upsetting the balance.

Epidemics are not mysterious, but explainable matters of biology. They are usually the result of the destruction of the natural enemies of some pest, or the introduction of a foreign pest without its natural enemies.

CHAPTER XXXI. **Pest Control.**—Artificial controls are usually temporary means of controlling an epidemic that is already started. If used soon enough they may exterminate the pest.

Permanent control of most pests and the prevention of new epidemics is best accomplished by restoring ecologically balanced conditions (=*biologic control*).

CHAPTER XXXII. **Forests.**—Forests have great ecologic importance, chiefly as soil binders and stream controls.

The commercial values rank forests among our important crops.

Forestry involves the protection of the forests, chiefly from overlumbering and fire, and the planting and care of new forests.

CHAPTER XXXIII. **Insects.**—Because of their small size, short life cycles, rapid reproduction, and great adaptability, insects are the ecologically dominant organisms.

As direct pests, insects make the Arctics and parts of the tropics uninhabitable by man. They destroy one-tenth of our agricultural crops. As forest pests they cause great losses. As disease-carriers they cause much misery and death, this being the chief reason why most of the tropics are uninhabitable.

Many insects are beneficial, serving as scavengers, predators and parasites of other insects, weed-destroyers, pollinators, and sources of some commercial products.

CHAPTER XXXIV. **Birds.**—Birds are great regulators of ecologic balance. Their rapid metabolism, ability to fly, and adaptive structures make them important scavengers, controls of mice and other rodents, weed-controls, and insect-controls.

CHAPTER XXXV. **Insects and Flowers.**—The relations of certain insects to the pollination of flowers serves as an instance of a close ecologic relation which, if broken, would result in the extermination of both groups of organisms.

CHAPTER XXXVI. **Galls and Gall Insects.**—These serve as another instance of a close ecologic relation, the insects being closely dependent, through the galls, upon the plants on which they occur.

CHAPTER XXXVII. **Fresh-Water Biology.**—Plants and animals which live in fresh waters are species that can live only under the peculiar environmental conditions found there. Their structures and habits are closely related to their environment.

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UNIT VII

How Plants and Animals Behave

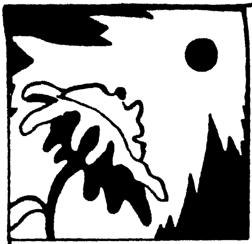
◆

The Biologic Science Called

BEHAVIOR

◆

REFLEXES AND TROPISMS
INSTINCTS
INTELLIGENT BEHAVIOR
SOCIAL WASPS AND BEES
ANTS AND TERMITES
PARASITISM
SOLITARY WASPS AND BEES
BIRD BEHAVIOR



Preview

1. What are honeybees doing when they "swarm"?
2. Does a sunflower really follow the sun? Why?
3. What insects might be used as thermometers?
4. What bird sits on its tail instead of its feet? Why?
5. Why do leaf-cutter ants cut leaves?
6. Why do leaf-cutter bees cut leaves?
7. Why do roots grow down and stems grow up?
8. How does a wasp manage to provide its young with meat that is neither dead nor alive?
9. Why should a hen want to sit on eggs?
10. How does a poplar tree locate a drain in which its roots may find water?
11. What insects herd milk-cows?
12. What creature travels 22,000 miles each year in order to get home?
13. What animal that walks backwards builds pit-falls in which to trap its prey?
14. How does a plant behave when it is a parasite?
15. Are any other animals beside man intelligent?
16. What bird uses saliva in building its nest?

You will find answers to these and to many other equally interesting questions in this unit.

CHAPTER XXXVIII

REFLEXES AND TROPISMS

What things may we observe plants and animals doing?

Why do they behave as they do? Why do they do certain things instead of other things?

We have already considered some of those physiologic activities of organisms that take place within their bodies; but now we want to study the more general behavior which we may observe in whole organisms. We shall also want to find the reasons for their behavior.

Reflexes

Everything that a plant or an animal does is a reaction to some stimulus, the result of some force which is the reason for its behavior.

Think of the time you placed your finger on the hot stove. You will recall that you jerked the finger off of the stove very quickly.

Why did you do that?

Stimulus and Reaction.—The question is not so easily answered as you might believe. Did you jerk your finger away because the stove was hot? That certainly was one of the reasons for your behavior. The heat in the stove was the outside reason, the *stimulus,* as we say.

But a stone or a piece of wood placed in the way of that same hot stimulus would not have moved as your finger did. You say, correctly, that that is because they are not live things. There is, you realize, some quality about living stuff which makes it liable to be affected by stimuli. That quality we call its sensitivity, and all protoplasm, plant or animal, simple or highly specialized, shows this quality. Sensitivity is one of the distinctive characters of living protoplasm, as you may recall.

Among plants and lower animals, all the protoplasm is more or less ready to receive stimuli. Among higher animals there are certain structures, the sense organs, which are more sensitive to stimuli than other parts of the body. Each sense organ is especially designed to receive a certain kind of stimulus. Thus, eyes are most affected by light, and ears by sound. The things that an animal does when it receives such stimuli are its reactions to the stimuli.

FIG. 397.—BEHAVIOR
"—what organisms do and why they do it."

Mechanical Nature.—But let us inquire how you knew enough to react that way—to jerk your finger away when it was burning?

You will answer, properly enough, that you didn't need to know anything about it, that you didn't have to *think* what to do, but that it "just happened." Such behavior, which occurs without the organism's having to decide what to do, is called mechanical behavior, because it somewhat resembles the actions of machines.

The meowing of the cat when its tail is pulled is not so different from the ringing of the bell when someone presses the button at the door. The door-bell can't help but ring; neither can the cat help what it does. The two things are related, with, of course, the great difference that the door-bell never knows, never becomes conscious that it has rung, while the cat, because it is made of living stuff, may know what it has done after it has meowed. It may surprise you to find how many of the activities of organisms are believed by scientists to be more or less mechanical.

Reflexes.—There are a number of different kinds of mechanical behavior. The simplest of these are called reflexes. They are mechanical responses of some part of an organism (not the whole organism) toward or away from the stimuli. The movement of the finger away from the stove was a reflex behavior. When the nerves in that finger were heated, an impulse started over them and went to your central nervous system (spinal cord or brain). There the impulse was transferred to other nerves on which it travelled back to the muscles of your arm or hand. The muscles in consequence were stimulated to contract, thus pulling the finger away from the stove. Rapid as your reaction may have been, it was still the final act, you see, in a chain of activities which was started by the heat in that stove.

All plants and animals, from the simplest to the highest, show reflexes. The man who blinks an eye before a moving object, the dog that moves its ear when it is stroked, the earthworm that pulls its head into the ground when it is touched, the morning-glory vine that coils around the post with which it has come into contact, and the dandelion stem which curls into spirals as you split it, are all showing reflex, mechanical behavior. Of course, in plants and in simpler animals there are no nerves to carry the impulses, but the protoplasm of the other tissues is sensitive enough to bring about a reaction. In the higher animals, many of the movements of the internal organs, such as the contraction and expansion of the digestive tract, the beating of the heart, and the movements involved in breathing, are reflex activities.

Tropisms

Nature of Tropisms.—Sometimes it is a larger part, often the whole creature that responds to stimuli. Even then, the behavior may be quite automatic. A mechanical behavior of a larger part of an organism is called a tropism, meaning a "turning." Although there is no sharp distinction between reflexes and tropisms, most simpler behavior may be classed as one thing or the other.

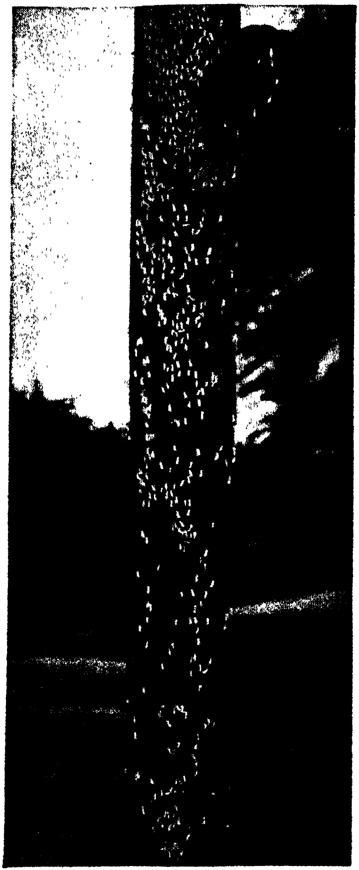

Courtesy U. S. Bur. Entomology

FIG. 398.—TROPISTIC RESPONSE TO LIGHT
Moths attracted by an electric arc.

Place a candle beside an open window, some summer evening, and watch the moth come flying to it, drawn, irresistibly drawn, by the light stimulus. Such behavior is tropistic. It is not a single part of the insect that responds, but the whole of its body. As the moth heads into the flame, it will singe its wings. It may flutteringly withdraw, its activities interrupted for the moment, but it will not be long before it will head into the flame again, and in the end it will likely burn itself to death.

That such behavior is mechanical, and shows no intelligence on the part of the moth, is evident enough when it is considered that not even certain death deters the creature from responding to the light stimulus. A tropistic response to a candle flame is of no advantage to the species to which the moth belongs. But to have resisted the light stimulus would have been more difficult for the moth than it would be for a hungry man to suppress his interest in a fine display of food set before him.

Positive and Negative Responses.—When the moth headed toward the light stimulus, its response was *positive.* Had it been repelled by the light, as a moth is repelled by sunlight, the behavior would still have been tropistic, but *negatively* so. We may expect to find that creatures are driven away from as often as they are drawn toward stimuli.

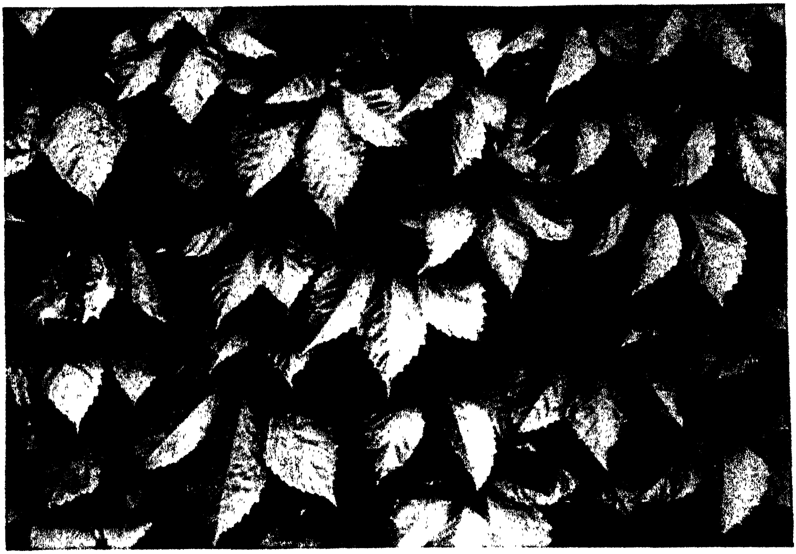


FIG. 399.—LIGHT REACTIONS IN THE WOODBINE

Each leaf adjusts itself to receive the greatest amount of light in a day.

The way in which an organism responds to a stimulus at one time in its life may be completely reversed at a later date. While young salmon react positively to heat, and in consequence migrate to the warmer waters of the ocean, older salmon become negative in their responses and migrate back to the colder waters of the mountain streams.

Tropisms in the Human.—Human behavior, even though sometimes appearing to be tropistic, really has a very different explanation. It is not correct to refer to the boy who frequents the swimming pool as showing a tropistic response to water. Reasoning, memory, and habit may all be involved in such a case. No behavior should be called tropistic which is anything more than mechanical. It seems that no purely tropistic behavior is ever shown by the human except in the first few hours after birth and in certain types of insanity. Human behavior is more often instinctive or intelligent, and in the latter event is not mechanical at all.

Most of the behavior of lower organisms, however, is reflex or tropistic.

Kinds of Tropisms

Responses to Light.[1]—Probably the most familiar tropistic behavior is the response to light. We have already referred to the moth that flies to the lighted candle. The earthworm retreats into the ground as a negative response to sunlight. House flies, fruit flies, wasps, and numerous other insects, confined in glass bottles, are likely to gather at the ends of the bottles which are nearest the lighted window or turned directly toward the sun. If the bottles are reversed, the insects turn, keeping their heads constantly toward the source of light. Sometimes they turn so quickly that the human eye cannot follow their movements. Sometimes the insects may be made to turn fifty times and more in rapid succession. If you will try this experiment, you will have no doubt that such behavior is mechanical, controlled by the light stimulus, and not reasonable at all.

Tropistic responses to light are commonly shown by plants. The sunflower head turns on its stalk as the sun circles across the heavens. The leaves of most plants adjust their positions on their stems so as to receive as much sunlight as possible. For the same reason, indoor plants regularly bend toward the window which is the most direct source of light. These are only a few of the many familiar instances of mechanical responses of organisms toward and away from light.

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[1] Known as *phototropism*, an awkward name which we need not use now.

Responses to Gravity.[1]—The commonest examples of tropistic responses to gravity are shown by plants. This explains why roots grow downward while the stems of plants grow upward. Gravity is the stimulus. One part of the plant responds positively, the other part negatively. Seedlings send their roots and stems in the right directions no matter in what position they are planted. If plants are first grown in normal positions, and later hung upside down, their roots will turn around and head downward, and their stems will turn upward. The positive or negative responses cannot be interrupted by merely inverting the plant. But if a growing plant

Courtesy Amer. Mus. Nat. Hist.

FIG. 400.—TROPISTIC REACTION TO HEAT

Lady beetles warming in the sun.

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[1] The behavior is known as *geotropism*.

be whirled rapidly on a vertical wheel, so that the gravity stimulus is continually changing its direction, then the roots and stems will not develop according to any particular system, but will grow in every direction.

Many of the simpler animals show responses to gravity. Many insects lay their eggs in the upper parts of plants, and many climb upward to find their foods because they are forced on by negative responses to gravity. They will climb a stick or an arm as readily, and they will always go upward, no matter how many times the stick or arm may be reversed. Other species as regularly climb downward, even pushing into the earth as far as they can go. Still other species wander in any direction, and you must not make the mistake of believing that they show any response to gravity.

Responses to Heat.[1]—These are shown by many animals. Ants most often gather under stones that are heated by the sun. Numerous moths are attracted by moderate heat, and some species overwinter in caves because the air in them at that season is much warmer than in the open. The insects that may occasionally be seen running about on the snow are so active because they react positively to heat and, therefore, negatively to the cold snow; and if they can find a warmer spot they crowd onto it.

Responses to Moisture.[2]—These are shown by the roots of most plants, and such things as willows and poplars send their roots long distances to secure an abundant supply of water. A drain or a sewer pipe that has a crack in it may soon become filled with such roots.

Most water-inhabiting insects are similarly responsive to moisture; and if they are thrown out onto the land, they will head back toward the water even though it is much too far away for them to see. Young house fly larvæ are attracted by moderate amounts of moisture, but older house fly larvæ, about to pupate, are repelled by water. One of the best ways to destroy house flies that may be breeding in the manure of the stable is to keep the manure moist and on a grating over a basin of water. The mature larvæ will burrow down into the lower part of the pile and then through the grating to try to find a drier place to pupate. Falling from this grating, they land in the basin and are drowned.

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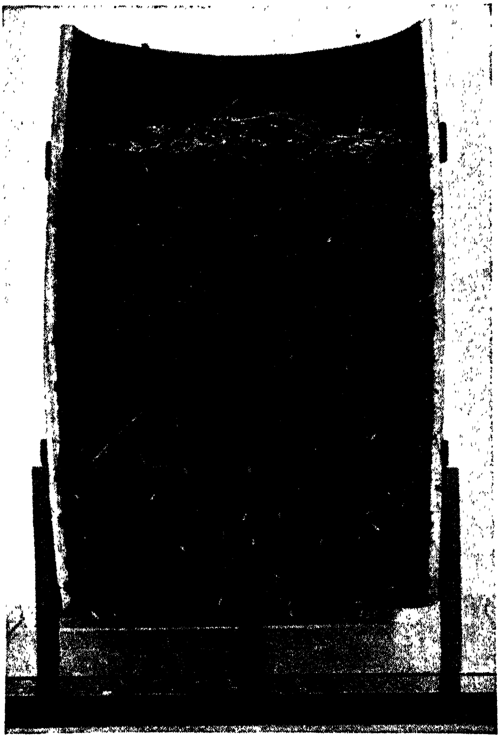
[1] These responses are known as *thermotropism.*

[2] Known as *hydrotropism.*



Courtesy Amer. Mus. Nat. Hist.

FIG. 401.—OLDER LARVÆ OF HOUSE FLIES AVOID MOISTURE

If the manure pile is kept moist, they crawl out of the bottom to find a drier place to pupate.

Responses to Pressure.[1] — Vines pressing tightly against supports are responding to pressure, and certain kinds of plants will lean toward trellises or walls while still a distance away from them. Similarly, cockroaches and some other insects press tightly into corners and crevices, best satisfied when they feel pressure on every side of their bodies.

Responses to Chemical Stimuli.[2]—These are familiar enough. Smell and taste are the two senses by which animals detect such stimuli. Flies are attracted to meat by its odor. Bees go to flowers, in part because of their odors. Male moths are attracted by the female odor at very great distances. Even plants show reactions to chemical stimuli. The pollen of flowers fastens onto pistils, and locates the eggs at the bases of the pistils through the action of chemical stimuli.

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[1] The response is known as *thigmotropism.*

[2] Known as *chemotropism.*

This is but a partial list of the kinds of tropisms, and many other illustrations might be found for each of those given. Keep your eyes open, and try to discover such behavior among the common plants and animals that are about you.

SUMMARY

1. In this part of our biology course, we shall consider what living plants and animals do and why they do it.
2. Everything that an organism does is a reaction to some stimulus. All protoplasm is sensitive enough to be affected by stimuli; the protoplasm of the sense organs of higher animals is especially sensitive and especially capable of receiving stimuli.
3. Most of the behavior of plants and of simpler animals, and even much of the behavior of higher animals, consists of responses that are almost as mechanical as the ringing of a door-bell when the button is pushed.
4. The simplest type of mechanical response is called a reflex. It is a response of only a part of an individual to a stimulus (*e.g.*, the blinking of an eye, the movement of a dog's tail when touched, etc.).
5. Mechanical responses of a larger part of an organism to a stimulus are called tropisms (*e.g.*, a moth flying into a candle flame). Responses may be positive or negative. The responses of an individual may vary at different times in its life. No true tropisms are to be observed in the normal human.
6. There are many kinds of tropisms. They include responses to light (*e.g.*, a moth at a candle; leaf change of position in the course of a day). There are responses to gravity (*e.g.*, roots grow down, stems grow up). Responses to heat are common (*e.g.*, beetles warming in the sun, flower petals opening after the day warms). There are responses to moisture (*e.g.*, roots of trees hunt water, water beetles crawl toward a pond). There are responses to pressure (*e.g.*, vines press against a wall, a cockroach crowds into corners). As common as any are the responses to chemical stimuli (*e.g.*, flies are attracted to meat, pollen is located on the pistil).

DEFINE

Behavior
Stimulus
Reaction
Sensitivity
Sense organ
Mechanical behavior
Reflex
Tropism
Positive response
Negative response

PROBLEMS

1. Explain as clearly as possible the difference between Physiology and the science of Behavior.

2. What illustrations can you give of reflex behavior that you have performed in the last twenty-four hours?

3. Describe exactly how you felt, and explain what moved your arm when, once upon a time, you touched a hot stove.

4. Give instances, other than those given in this chapter, of tropistic behavior that you have actually observed in some plant or animal, that show responses to light.

5. Similarly give instances of responses to gravity.

6. Similarly give instances of responses to heat.

7. Similarly give instances of responses to moisture.

8. Similarly give instances of responses to chemical stimuli.

9. Give instances of behavior in an animal (other than the human) that is not reflex or tropistic.

10. Give an instance of human behavior which seems to come very near being tropistic. In what way does it differ from a true tropism?

11. It is commonly advised that bulbs of onions, tulips, narcissi, lilies, etc., should be planted with their bases down and their growing tips up. Is this *necessary* or *desirable?* Discuss.

12. Not all roots grow directly downward, nor all stems directly up. Can you explain this?

13. Will the root system of a plant spread further in a poor soil or in a rich soil? Why?

14. List the differences between a telephone system and the nerve path involved in a reflex.

15. What are the chief differences between a reflex in a plant and a reflex in an animal?

16. What are the chief differences between tropisms in a plant and tropisms in an animal?

17. Reflexes and tropisms are sometimes considered the same thing (and then both are called reflexes). Is this correct? Carefully consider both sides of the question.

CHAPTER XXXIX

INSTINCTS

Much behavior is not so simple as the reflexes and tropisms which we have considered. The more complicated chains of inherited, mechanical behavior are called instincts.

Although plants engage in few activities that are more than tropistic, a large proportion of the things that animals do is instinctive.

Chains of Behavior

For instance, consider the case of the old hen that wants to set.

She is no longer satisfied to stay in the hen-yard. If possible, she will steal out and find some hidden spot, perhaps in the haymow, where she will wallow out her nest. She will lay her eggs, a dozen or fifteen of them, and then she will set for all the long time the eggs must be kept warm before they hatch.

Finally, some day, she will lead her family of tumbling chicks up to the kitchen door. She will be very proud of them. She will worry over them; and she will scratch up food for them. She will cluck and scold to keep them together; and she will fight the old cat with such ferocity as only mother hens show. At each sundown she will cover and coddle the feathery balls, keeping them warm, and protecting them through the hours of the night.

Mother hens do such things.

But have you ever asked *why* they do them? The old hen hasn't. She doesn't know where she learned them. She would tell us, if she could talk, that it is "natural," or *instinc-*

tive, as we say, for her to behave so, and she would be surprised that we should want any better explanation.

Now, it is apparent that instincts such as the hen has shown are chains of behavior, and not such single and simple reactions to stimuli as reflexes and tropisms are.

Made of Simpler Types of Behavior.—The chains seem to be made up of simpler activities. Thus, the very first thing that the hen did, the wandering away from the hen-yard, bore a resemblance to a tropism. Her stimulus was partly in the weather of the springtime, and partly in her own internal reproductive organs, which were undergoing considerable development at that season.

Courtesy U. S. Bur. Animal Husbandry

FIG. 402.—THE MOTHER HEN

Wandering away, the hen brought herself to the second stimulus, the loose straw which invited her to wallow and make a nest. The nest was one of the stimuli to her egg-laying apparatus and, acting reflexly, those organs began producing eggs.

When the eggs had accumulated to the proper number in the nest, they provided the stimulus necessary to put a stop to egg-laying. Had the nest been robbed, the hen could have gone on producing eggs for some time, as most laying hens ordinarily do. But had we provided the proper number of eggs, we might have stopped the hen before she had ever begun to lay in that nest. Indeed, the farmer may, to some extent, regulate his supply of laying and setting hens by these traffic signals, as they are, which tell the birds when to go, and how far to go, and when to stop.

You see, it is not merely the eggs that she has produced, but some number of eggs in her nest that provides the stimulus limiting the hen's laying. Yet she cannot count.

If we were to pursue our analysis to the end, we would continue to find a chain of stimuli bringing about a chain of activities. Each behavior in the chain may, more or less, provide the stimulus which calls forth the next behavior, and so such a chain is usually a securely established succession of events.

The Chains May Be Broken.—Sometimes it is possible to make a chain begin in the very middle by providing the appropriate stimulus. A farmer does that when he gives incubator-bred chicks to a hen that hasn't actually raised her own family.

A similar situation is illustrated in certain observations made on a species of solitary wasp. This insect digs holes in the ground and places its eggs in the holes with paralyzed caterpillars designed as food for the babies. Then the holes are closed with earth. Immediately after one wasp had completed this task, she was offered a second caterpillar. This was a stimulus to her to bury the thing, so she promptly opened up her hole. But in the hole she found the first caterpillar, and that was a stimulus for closing the hole. She promptly did that. But then the second caterpillar was spied again on the ground, and that led to the further opening of the hole. And so the performance was repeated until the wasp became exhausted. Clearly it is sometimes possible to start instinctive behavior at any point by providing the proper stimuli.

That this is not always possible will be apparent by considering that most birds, unlike the hen, cannot be persuaded to take care of babies other than their own. They must have built the nests for them, laid and incubated the eggs, and fed the nestlings from the very beginning if they are to raise them.

Many instincts are chains of few links. When the mother hen spreads her wings and covers her chicks as a hawk flies overhead, she engages in hardly more than a single action. Such behavior is more like a tropism, but it is peculiar in being a response that is neither toward nor away from the stimulus (the hawk) as a tropism would be, but toward another object, the chicks!

There is, moreover, much behavior that is even more truly on the border line between instincts and tropisms, and it seems likely that instincts have come, in the course of evolution, from simpler, mechanical types of behavior.

Mechanical Nature

Even though instincts are not such direct responses as tropisms, they have much of the same mechanical nature.

Watch a frog crawl carefully toward an earthworm, set itself in a tense position convenient for pouncing, and then suddenly dart out its tongue at the red thing. If you dangle a bit of red cloth before the amphibian it will seize it in the same way. But a motionless, red object, even though it be a live earthworm, will bring no response from the frog. It seems as though moving and red objects set an instinctive machinery running in the frog, and the results are not always what an intelligent animal would demand.

The behavior of the chickens that dash to cover when a hawk goes overhead is similarly mechanical. They will do the same thing when an airplane flies by.

There is a record of a wasp nest that contained one baby wasp and thirty larvæ of a parasitic fly, real enemies of the wasp. The mother wasp had provided food for all of the thirty-one mouths. This was surely a mechanical, and not an intelligent performance.

Certain kinds of caterpillars travel in columns to hunt for food. Started around the edge of a circular disc, they have been made to travel for seven whole days in a continuous march, over and over the same path, accomplishing nothing, getting nowhere, but mechanically obeying the commands of their instincts.

Courtesy Smithsonian Inst.

FIG. 403.—AFRICAN LEOPARD
A cat in behavior, as well as in structure.

In thinking over the unreasonableness of instinctive performances, my memory reverts to a thing that I once watched from a bridge that spread over a broad stream. Some children, down on the river's bank, were playing with a bulldog. They were throwing sticks into the water, and the dog was dashing in and bringing them back to shore. Finally one child threw a barrel hoop far out into the stream. In a moment the dog had it, but in taking it into his mouth he had turned the hoop under his head, and fastened down his front legs so he couldn't swim. Immediately he began drowning.

The children threw sticks and stones, and I yelled to try to shake the dog's hold. But bulldog grips are not so easily broken. It would have been reasonable for the animal to have let go of the hoop, but a mechanical thing called instinct was in control! The dog went down once, and twice, before some men in a boat pulled it out. They laid it on the back seat of the craft, and worked over it, and it revived just as the hoop came floating by. Instantly the dog was after it, and immediately it had pinioned its legs, and was drowning again. Such is the blindness of instinct.

Instincts Are Inherited

Now, if a hawk should fly over some day when a tabby cat was out with her kittens, you would hardly expect to see her covering them as a hen would cover her chicks. Because, you say, a cat isn't born that way! Because the cat's ancestors have been doing other things through the ages, and the cat has inherited its ancestor's ways of behaving just as surely as it has inherited its whiskers and its tail.

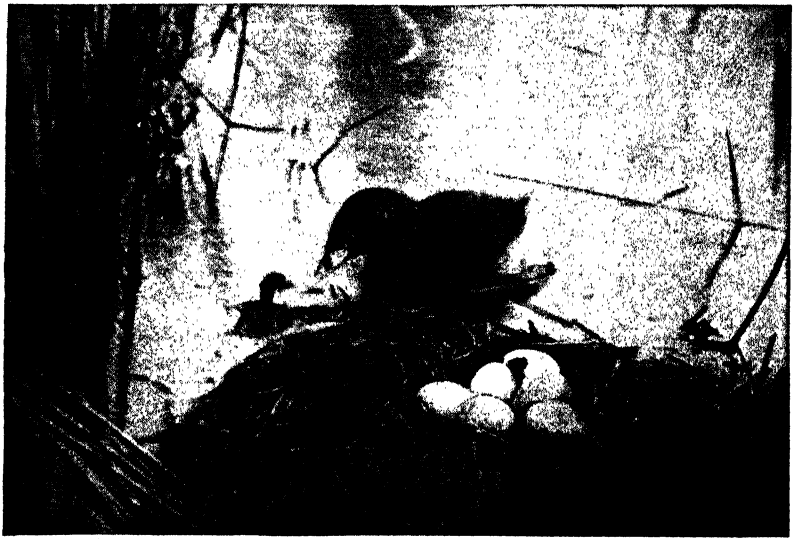
There isn't very much to be said on this subject of the inheritance of instincts. It is a very obvious fact about which, in the minds of biologists, there seems little to debate. But it is an important thing for you to realize.

Unconscious Adaptations

Even though they are mechanical, instincts usually accomplish something of advantage to the animal or its species. They are often as adaptive and as useful to an organism as any structural adaptation.

Instincts are concerned chiefly with the three important things in an animal's life, namely, the finding of food, the finding of protection, and the chance to reproduce so the species may survive.

Among the highest animals, especially with man, these three things are often accomplished in roundabout fashions, and sometimes by the use of reasoning intelligence. Not only our work, but our play, and all the things that keep us happy, serve to help us get the most out of life.



Courtesy A. A. Allen, Cornell Univ.

FIG. 404.—INSTINCTIVELY TAKING TO WATER

Young grebe just out of the shell, but swimming with never a lesson.

But among the lower animals, the three things are usually accomplished by such mechanical types of behavior as reflexes, tropisms, and instincts; and even a man facing an unusual condition, starvation, a deadly enemy, or what-not, may become a purely instinctive machine.

Reproductive Instincts.—Typical, instinctive behavior in reproduction has already been described (Chapter XIV). Mating, nesting, and egg-laying, the care of the young, and social activities are, with most animals, instinctive and concerned with the rearing of new generations of individuals.

Instincts of Protection.—You are familiar with much of the instinctive behavior by which creatures protect themselves. The boy that is attacked may instinctively stiffen his shoulders and double his fists. The dog secures the same protection in a somewhat different way. The cat first runs, and then she turns and arches her back, stands on her tiptoes, and spreads her claws, and tells the world about it. The snake coils while it gathers its muscles for a sudden spring. The bee flashes the end of its abdomen under and forward, and stabs in its sting just as its poison sacs are opened. The ant, lacking a sting, bites its foe and then sprays the wound with acid secreted in glands at the tip of its abdomen. The earthworm—poor earthworm—merely draws back into its hole, but it has, none the less, done the thing best designed to protect its simple body.

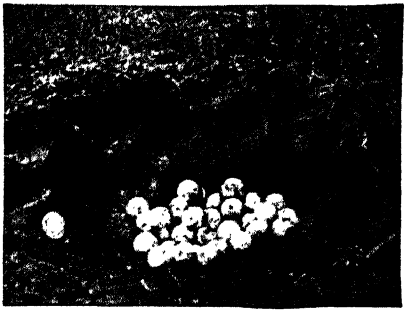
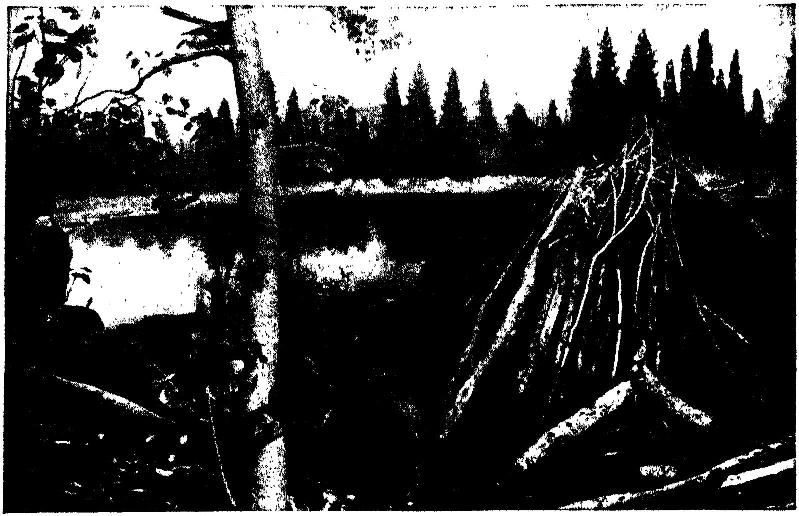

Courtesy D. T. Jones, Ind. Univ.

FIG. 405.—REPRODUCTIVE INSTINCTS IN A REPTILE

This snapping turtle had buried its eggs 7 or 8 inches below the surface. For size, compare with the half dollar at the left.

Many animals prepare in advance to protect themselves. The fox and the prairie-dog, and many other mammals, dig their holes in the ground. The piddock (a clam-like mollusc of Europe), hollows out its hole in solid stone, entering when small through an opening which is so narrow that, although the clam cannot leave when it grows larger, no enemy can get in. Insects make mud, paper, or silk nests, dig tunnels in the earth, mine in the green tissues of flat leaves, and cut galleries in solid wood. Spiders spin silken tents in which they hide; or dig holes in the ground, building grass and stick turrets at the top as additional protections; or they may fashion mud-and-grass-and-silk doors that work on hinges and cover up the entrances to their holes. Even the behavior of the dog that shakes the rain off its coat, and of the bird that water-proofs its feathers from the oil-glands at the base of its tail, serves as a protection.



Courtesy Amer. Mus. Nat. Hist.

FIG. 406.—INSTINCTIVE BEHAVIOR OF THE BEAVER
Trees are cut for food, streams are dammed, material is gathered for the lodge.

Food-Gathering Instincts.—No less familiar to us is the instinctive behavior by which animals secure food. There is the cat that creeps quietly, slowly, toward the mouse, which lies in quivering silence, that suddenly pounces upon, tosses, and catches her victim, poking it, allowing it to creep a distance away, pouncing again, and then repeating the performance. There is the dog that digs its bone into the ground at a spot where it may later gnaw without interruption from other canines; and so fixed is this behavior that a house dog may

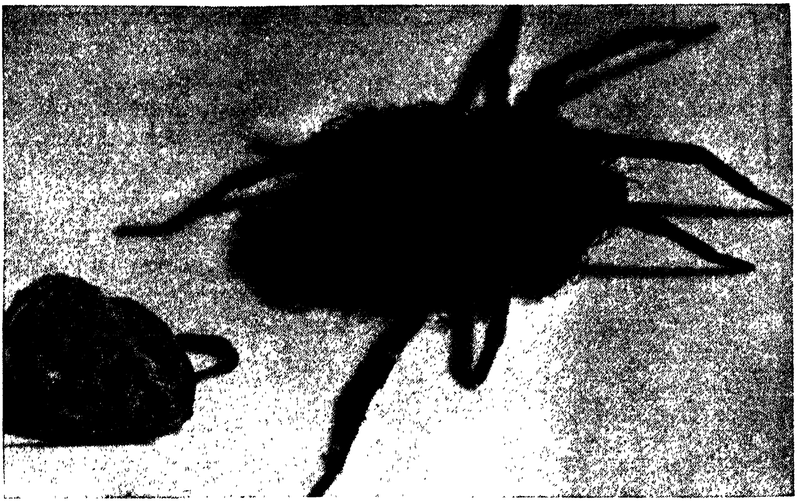
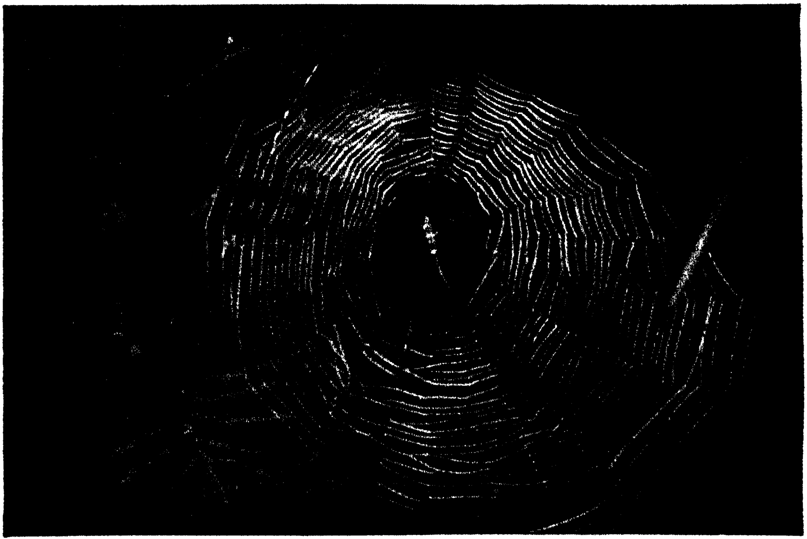


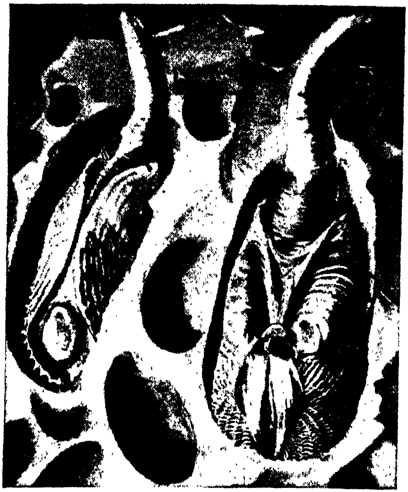
FIG. 407.—A WOLF SPIDER, ITS SILKEN EGG CASE, AND ITS BABIES (BUT WHERE ARE THEY?)



Courtesy J. H. Emerton

FIG. 408.—INSTINCTIVE BEHAVIOR FOR OBTAINING FOOD
This spider builds its web and waits until insects are caught in it.

bury its bones under the parlor rug. There are the squirrels that provide stores for their winter use. There is the woodpecker that takes its food directly from tree trunks; the swallow that takes it out of the air; and the long-necked clam that pushes its "neck" through the mud where the sea water may wash in a meal. There is the dung beetle that packs solid balls of manure which it may roll over the countryside for hundreds of yards before it buries the viands in a secluded hole that will serve as a private dining-room.



Courtesy D. Appleton & Co.

FIG. 409.—PIDDOCKS IN A ROCK
Part of the rock broken away to show the molluscs.

And there is the **ant-lion** that lives in a sand-pile. By jerking backward and downward into the sand, and by travelling in circles, flipping back its head and throwing out sand, the insect has made a funnel-shaped pit that is, perhaps, an inch or two deep. It now lies under the sand at the bottom of the pit, with nothing but the tips of its long, curved, and sharp jaws protruding. If you watch the ant that has wandered to the edge of the pit, you will see the advanage of these tactics. The soil gives way beneath the ant's feet, and the fated insect tumbles to the bottom of the pit. Immediately the ant-lion helps stir up the sand, and in its excitement it may throw a perfect shower of grains that knock back the ant that is trying to climb out of the trap. Finally the lion gets its jaws fixed on the victim, and sucks ant juices for dinner.

Such are the complicated, instinctive workings that may be employed to feed animals!

Emotions

While behaving instinctively, animals often feel very peculiarly. You will probably recall that when you were, instinctively, protecting yourself—or just plain fighting!—you felt strangely excited and angry. Others of your instinctive actions have given you peculiar feelings of pleasure. Still other conditions may have aroused fear in you.

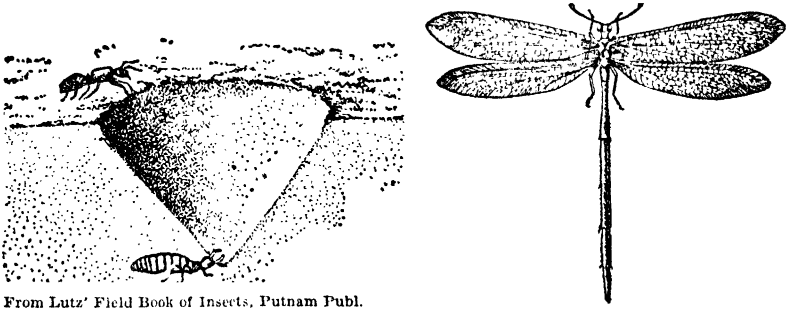
Courtesy Dr. Y. Sjostedt, Stockholm Mus., Sweden

FIG. 410.—DUNG BEETLES ROLLING BALLS OF DUNG

Such peculiar feelings that are so often associated with instinctive behavior are known as emotions.

It is sometimes an interesting question whether the instinctive behavior arouses the emotion, or the emotion arouses the behavior. Does a boy fight because he is angry, or is he angry because he fights?

At any rate, folks who are highly emotional and sentimental, as we say, meaning those who are easily aroused into an emotional excitement which they do not try very hard to control, are the people who behave most instinctively and very often most unreasonably. While instinctive behavior is remarkably successful, even in the human, we possess highly developed reasoning powers which should at times guide our actions. The human becomes most different from the lower animals if he doesn't give full play to his instincts and emotions too much of the time.



From Lutz' Field Book of Insects, Putnam Publ.

FIG. 411.—THE ANT-LION, LARVA AND ADULT

Instincts May Be Modified

What we have said about the mechanical workings of instincts must not be taken to mean that they never vary or may never be modified. No two individuals of a species ever behave exactly the same, even though they may be most instinctive in their activities.

Moreover, the instinctive performances of an animal may be changed by the experiences it meets in its lifetime. A dog that is whipped for bringing its bone indoors may modify its future behavior accordingly. The robin that instinctively uses dull grass and twigs for its nest, may substitute the bits of colored worsted that you have thrown out. The human, born with a goodly dose of instincts, learns to control the less profitable ones by his reasoning.

Because instincts may be modified by memory and reasoning, it is difficult in any particular case to be sure that the behavior is purely instinctive. The following chapters on the behavior of certain insects and of birds will give many instances of what seem to be instincts.

SUMMARY

1. Chains of inherited, mechanical behavior are called instincts. Consider the behavior of the setting hen. Plants engage in few activities more complicated than tropisms, but a large proportion of the things that animals do are instinctive.
2. Such chains of behavior consist of reflexes or tropisms, each of which provides the stimulus for the next link in the chain.
3. Such chains may be interrupted if something happens to prevent the proper stimulus from developing. For instance, hens whose nests are robbed may be made to continue laying, and they may not proceed to setting at all.
4. Instincts are as mechanical as the reflexes and tropisms of which they consist.
5. Instincts are inherited. The behavior of each species of animal is as distinct as its physical structures—for the same reason, namely, because of the genes which it has inherited.
6. Much instinctive behavior is adaptive, as useful to the organism as finger-nails or other structural adaptations. Most instinctive behavior is concerned with the reproduction, protection, and food-gathering activities of animals.
7. Emotions are the peculiar feelings that are often associated with instinctive behavior. Does the instinctive behavior arouse the emotion, or does the emotion arouse the behavior?
8. These chains of behavior may be interrupted, modified by experience, etc., etc. No two individuals are alike in their behavior. The differences are the result of the same things that produce differences in the structural characters of individuals, namely the environment acting on their body cells, hybridization, and mutation.

DEFINE

Instinct

Emotion

PROBLEMS

1. What cases of instinctive behavior can you find in Chapters I to XXXVIII in this book? Take time to study this problem well.

2. Give an instance of wholly or nearly instinctive behavior in the human.

3. Consider any example of instinct other than the setting of the hen. Show from what reflexes, tropisms, etc., the chain is built.

4. Give several illustrations showing that instinctive behavior is inherited.

5. Does the instinctive behavior follow the emotion, or does the emotion arouse the behavior? Discuss, giving specific illustrations.

6. As terms are defined in this book, which of the following are instinctive in the human: blinking an eye, fighting, fear of snakes, putting on of clothing or bed covers when cold? Discuss each.

7. Give several instances of food-gathering instincts that you have actually observed in some animal other than man.

8. Give an instance of individual variation in instincts in some species of animal.

9. Give an instance (not in this chapter) of instinctive behavior that was disadvantageous—perhaps distinctly harmful—to an animal.

10. Why are there no instincts in plants?

11. Find instances, in this or in other texts, or from your own observation, of instinctive behavior that was of more advantage to its young than it was to the parent animal which showed the instinct.

12. How would you explain instincts which are advantageous to the young but not to the parental animal that shows the instinct?

13. Give an instance of instinctive behavior that shows up in adults but not in the young of the same species.

14. Give an instance of instinctive behavior that shows up in the young but not in the adults of the same species.

15. If an instinct does not show up until the animal becomes an adult, is it possible that the instinct is inherited? Explain.

16. Some scientists consider instincts more valuable to the human than some other people ordinarily rate them. What have you to say on this question?

CHAPTER XL

INTELLIGENT BEHAVIOR

We may call behavior intelligent if it shows that an organism has profited by the experiences it has met in its lifetime. The cat that has been whipped for bothering the milk bottle, and that consequently avoids the occasion for further punishment, shows a sort of intelligence.

While reflex, tropistic, and instinctive behavior are inherited racial characters, more or less alike in all the individuals of a species, intelligent behavior must be learned independently by each individual after it is born. Only the ability—or the lack of ability—to be intelligent may be inherited. Cats are not born with a knowledge of the particular milk bottles that are to be avoided, but they may inherit the ability to acquire that useful information.

Memory and reasoning are the particular kinds of intelligence which we shall consider.

Memory

A memory is a record of past experience. It provides a stimulus for behavior long after the original experience is gone.

Everything, dead or alive, may to some extent be modified by its experiences. If you hit a stone with a hammer, you will leave an immortal record of the blow. Perhaps the crack will be so slight that you cannot see it, but time will bring it out. Foul weather will work along it, weights, strains, and more blows will find the weak spot, lichens and the roots of trees will work into the crack. Some day the stone will go to pieces, shattered by the accumulation of all its past experiences.

But if dead things are so affected, living protoplasm is more easily changed by what it meets.

Primitive kinds of memory are to be found in all plants and animals, even the simplest. After a protozoon has met a stimulus several times it reacts more quickly than it did the first time.

Courtesy C. D. Walcott and Smithsonian Inst.

FIG. 412.—FEEDING THE GROUND SQUIRREL NAMED GRANNY

This squirrel met the biologists in the wilds of British Columbia. Four years later it responded when called, giving clear evidence of remembering its former experience.

Among the higher animals the ability to remember is best developed in the kinds of protoplasm of which nervous systems are made and (among the vertebrates) particularly in that mass of nervous tissue which we call the brain. It is not known what changes are made in brain tissue by the experiences which an animal meets, but apparently the changed nerve stuff provides the basis for the memory behavior of the creature.

Memory behavior cannot have originated evolutionarily from such mechanical things as reflexes, tropisms, and instincts, for the ability to remember is shown even among the simplest organisms in which tropisms and instincts are only poorly developed.

In Vertebrates.—Man is not the only animal that shows memory intelligence. Dogs have remarkably clever memories, as you may know. Birds remember the locations of their nests, distinguish (by memory) the calls of their own young from those of other nestlings, lose their fear of particular persons who have fed them, know the particular cats which are the most bothersome in the neighborhood, and know a thousand other things which they have learned through their experience. Their migration routes, at least their return routes, are in part located by their memories of landmarks along the way. They come back to their old nesting-grounds year after year, and thus show that they may remember things over a considerable period of time.

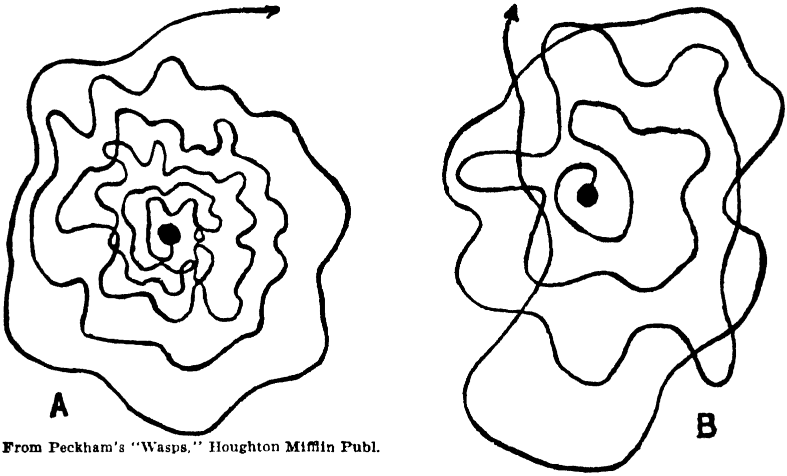
In Insects.—Many insects, particularly ants, bees, and wasps, have remarkable memories; and in later chapters we will recount not only the instinctive, but the memory-intelligent behavior of these tiny animals.

Ants that once locate a store of food, in the woods, in the fields, underground, or in your pantry, will return again and again to gather the provisions. That they come long distances directly to the particular spot where food is to be had, instead of to any of the unlimited number of other places they might go, is to be credited to their memories of what they will find in the spot which they are revisiting.

Similarly, bees that have located a rich lot of nectar in a particular garden or field will return day after day until they have exhausted the supply. Then they will stop coming. That they first found the nectar may be credited partly to accident, and partly to the odor of the flowers; but they continued their visits apparently because they remembered where food was to be found, and they finally abandoned the fields because they learned and remembered that they had secured all that was worth while from the flowers there.

In one experiment a dish of honey was placed where bees would be attracted, and after the insects had learned to come regularly a bit of quinine was mixed with the food. One taste of the bitter stuff, however, was enough to make each bee forsake the place, its memory henceforth warning it away from further trouble.

Repeated observations and experiments have proved that wasps and bees remember landmarks that they use to find their nests. The first time such a creature sets out from its home, it circles about in a closely wound, irregularly spiral path that only gradually leads away from the spot. Finally, however, the insect darts away in a straight line. When it returns it may be seen hunting about, here and there, until finally it locates its hole from the landmarks it learned as it left the nest. The second time that the wasp goes abroad, it makes a somewhat shorter locality study. On successive occasions the explorations become still more brief, until they are finally omitted altogether. In the original study great numbers of landmarks were noted, but in time a certain few of them, the more conspicuous ones, were fixed upon as the only necessary guides.



From Peckham's "Wasps," Houghton Mifflin Publ.

FIG. 413.—A WASP'S LOCALITY STUDIES

The nest hole in the center. The second study was more brief because it was aided by the memory of the first study.

That the wasp or bee depends upon these remembered landmarks is very easily proved. If some of the conspicuous objects in the vicinity of the hole be disturbed somewhat, a bush broken, a stick shifted along the ground, or a bit of paper taken from or added to the landscape, the poor insect is all upset. Facts don't accord with its memories. Now it may hunt for hours and hours without finding its front door. Even though it may walk over the hole a dozen times during the search, it may not know it for its own, for the sign-posts read differently.

You may easily try out these experiments, and hundreds of others that are as interesting. Then you will become convinced that some of these organisms have really capable memories.

Simple Reasoning

Reasoning is a process of putting together or choosing between two or more things, perhaps between several memories which are called to mind at one time.

It is as though you stood at a cross-roads. The sign for the one path, and the landmarks along it, bring up memories of all that you know about that road, what you may have found on it one time when you went that way, and everything that anyone has ever told you about it. You review all the memories that concern the other road. You juggle the two sets of stimuli, you squelch one set, and you allow the other to lead you on your way. You have reached your conclusion by choosing between stimuli.

Sometimes you squelch the one set of memories by making additions to it, by associating it, for instance, with thoughts of the difficulty of the road, of the dog that lives on it, of the long, lonesome and roundabout way by which it gets to your home, and of any number of other sad things. You are tying tin cans and stones to your thoughts of that road, and throwing them overboard. Meanwhile you are associating the other road with memories of apple pie and doughnuts, with a warm fire and a soft bed. You make that set of conditions so attractive that you have to give in to it.

When older folks advise us to avoid evil and follow good, they do not mean that we will never have to meet evil. They want us to learn the art of weighing down unprofitable things in our thoughts. As Carlyle pointed out, we may not be responsible for the birds (memories) that fly over our heads, but we can keep them from roosting in our hair!

Reasoning seems to be a higher evolution from simple memory intelligence. It is not surprising, therefore, that it is sometimes difficult to decide whether certain acts of an animal show reasoning intelligence or merely a high degree of memory intelligence, for there is no clear-cut line between the two things.

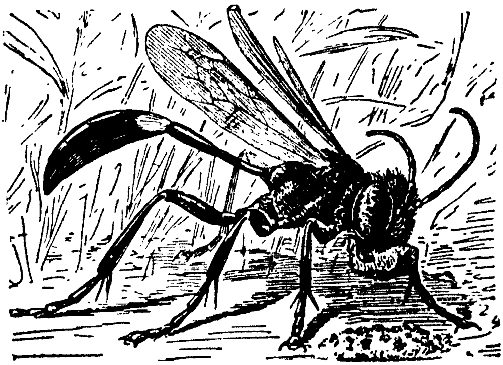
Among Vertebrates.—We know that man has a capacity for reasoning that is far beyond that of any other animal, but it should also be noted that a great many of the activities of the human are nothing more than memory, instinctive, or reflex behavior.

Below the human the dog and the horse are most generally credited with reasoning. Every dog-owner can recite instances in which the four-footed animal has shown remarkable intelligence. Investigate the tales which you can hear of these things, and see whether they show reasoning or something else.

There is no positive case of reasoning among the birds or the lower vertebrates.

Among Insects.—Among the insects there are a few records which are commonly thought to show reasoning intelligence. These are all among the higher wasps. One ground-inhabiting species was seen to bring a large spider to her hole, but after considerable tugging had shown her that the thing could not be forced into so small an opening, she hung it among the clover blossoms and set to work to enlarge her hole. Now, this would seem to show some reasoning intelligence, for the wasp apparently carried memories of the size of the spider, of the original size of the hole, of the vain struggle to get the spider into it, and perhaps of what had happened once upon a time when she pulled some other spider into some larger hole. The behavior of the wasp thereupon was determined by all of these several memories brought together.

Still more remarkable is the case of the thread-waisted wasp which, after burying her egg with a paralyzed caterpillar, filled up her hole, and at the last pounded the dirt down with a tiny stone which she held between her jaws. Here was a tool used for a definite purpose by an insect! It was such an attempt as would have done credit to primitive man. If only a single biologist had observed such a performance we might have doubted it, but no fewer than eleven different persons have seen similar wasp behavior. Is it possible that these wasps use the stones because, by their memories, they know the advantages of pounding with such tools, and choose the more advantageous method? If so, they are showing reasoning intelligence.



After Peckham. Courtesy Houghton Mifflin Co.

FIG. 414.—A SOLITARY WASP USING A STONE AS A TOOL

Higher Reasoning

Some of the reasoning of which the human is capable seems so far beyond the abilities of any of the lower animals that we do not thoroughly understand it, although it does seem related to the simpler sorts of intelligence which we have already considered.

The human often chooses to follow paths which are not attractive at the moment, and which indeed may be very difficult or even dangerous, but which are worth following because of the advantages to be had in the long run. One climbs mountains not so much for the difficult trails as for the rewards that await at the summits. The human shows himself very different from the other animals when he considers the final results of his choices and his actions more than the immediate attractions of a situation. Will, will-power, and wisdom are some of the indefinite terms commonly connected with such behavior.

Courtesy heirs W. M. Cary, and Amer. Mus. Nat. Hist.

FIG. 415.—AGAINST ODDS, FOR THE REWARDS THAT AWAIT AT THE END OF THE TRAIL

The winter supply train, from a painting made by W. M. Cary on a pioneer expedition in our Far West.

Individuals may differ considerably in the degree of intelligence which they show. The more highly intelligent individuals are the ones who, in addition to remembering facts, use their information in reasoning out new problems as they are met. One may know (remember) any number of facts of biology, for instance, without showing unusual intelligence. But if you are able to apply what you have learned in explaining the affairs of your every-day life, you are a superior person.

Habits

Finally, some of the activities of individual organisms, even the most intelligent of them, are repeated so often that they become more mechanical and easier to perform. Then they are called habits, no matter whether they were reflexes, tropisms, memory, or reasoning behavior to begin with.

While it is a misfortune to acquire certain habits, it is fortunate for us that so many of the things which we have to do over and over again in the course of each day may be made so mechanical that they require little intelligent attention. Walking, climbing, skating, swimming, diving, and typewriting, even though partly reflex muscular movements to begin with, become easier with practice—that is, as they become habits. If we had to give our whole intelligent attention to every step that we take, we would still be walking like babies. If every pianist had to give as much thought to his fingers as a beginner gives his, there would never be more than beginners among the musicians of the world. The novice at diving hits the water with a splash because he cannot think quickly enough of all the things he should do after he leaves the spring-board, and because he has not yet repeated his efforts often enough to have made the proper things so mechanical that they take care of themselves.

If you will stop to number the things of daily life that are now easier for you than they once were, because they have become habits and more or less mechanical behavior, you will immediately want to acquire more of the worth-while habits that are within reach of the human.

SUMMARY

1. Behavior is intelligent if it shows that an organism has profited by its experience. Intelligent behavior may be memory or reasoning.
2. Intelligent behavior is not inherited; it is acquired from the experiences which the individual meets within its lifetime. The ability to be intelligent may be inherited.

3. Memory is a record of a past experience. The protoplasm of all plants and animals is, in some way, changed by the experiences it has had. Among higher animals, the protoplasm of the brain is the material most capable of being affected by experiences.

4. Memory is well developed in some mammals (man, dogs, horses), in birds, and in many insects. Much of the behavior of ants, bees, and wasps is influenced by their well-developed ability to remember.

5. Reasoning is a process of putting things (often memories of past experiences) together and choosing which will provide the stimulus for the future behavior. It is what you do at the cross-roads, where you choose the route you will follow.

6. Reasoning is well developed only in man and in some of the anthropoid apes. There are cases among dogs and horses. There are none among the birds. There are a few cases among the wasps.

7. The highly developed reasoning ability of man—his ability to look beyond the immediate attractions of a situation and to consider the final results of his choices—makes him very different from other animals.

8. Any type of behavior, mechanical or intelligent, may become more mechanical and easier to do as the result of repetition. The behavior then becomes habit. Habits may be assets or misfortunes. The worth-while habits will help materially to make life run more smoothly and profitably.

DEFINE

Intelligent behavior
Memory
Reasoning
Will-power
Wisdom
Habits

PROBLEMS

1. Show that both memory and reasoning are types of intelligent behavior.

2. What instances of memory behavior have you ever observed in an animal other than man (and other than the cases given in this chapter)?

3. Thinking is another name for one of the intelligent types of behavior. Which one?

4. Can you give an instance of a dog or horse showing reasoning intelligence? Are you sure you could not explain it as instinctive or memory behavior?

5. In which of your subjects in school are you most often asked to use your memory? In which are you most often asked to reason?

6. Give a case in which you reasoned out a conclusion. Analyze it (as we did our cross-roads experience) to show exactly what you were doing.

7. Give instances of habits that began as reflex behavior.

8. Give instances of habits that began as something other than reflex behavior.

9. List the five things, reasoning, reflex, memory, instinct, and tropism, in an arrangement that will show the path or paths of evolution of those types of behavior.

10. Are habits adaptations? Carefully consider your answer.

11. List some habits advantageous to the human.

12. List the phyla and classes of plants and animals in which memory is to be found.

13. List the phyla and classes of plants and animals in which reasoning intelligence is to be found.

14. Give instances from man or the other animals showing individual variation in memory ability.

15. Give instances from man or the other animals showing individual variation in reasoning ability.

16. Which is more important in determining a man's intelligence: heredity or environment? Why?

17. Which is more important in determining reflexes and instincts: heredity or environment? Compare your answer with that of the previous question.

18. What percentage of your daily activities do you guess are mechanical and what percentage intelligent? Write down your guess, and compare it with others in the class.

19. After writing your answer to the above problem, make a record of your activities for one hour, classifying them as mechanical or intelligent. Compare with others in the class.

20. Compare man with the other animals in regard to reflexes, tropisms, instinct, memory, and reasoning behavior.

CHAPTER XLI

SOCIAL WASPS AND BEES

Here are the stories of three groups of insects that live in social colonies. In their behavior these animals are largely concerned with the social organizations to which they belong.

Social Animals

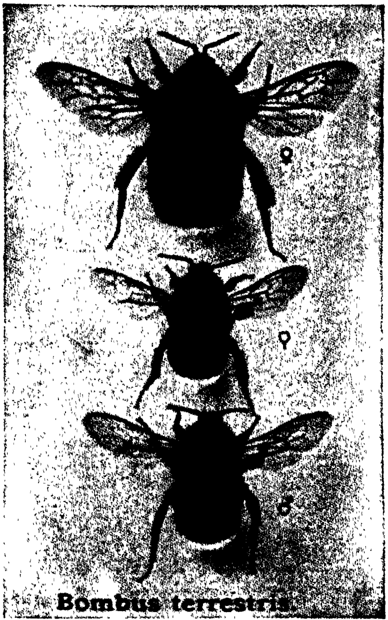
Most animals live singly, each individual going its own way, hunting all of the food that it eats, sharing with no other animal and showing no special interest (except sexual) in other individuals of its own species.

Distinctive Qualities.—But a social animal lives in intimate relation with numbers of other individuals, helping build the roof that covers all of the members of the colony, storing food in a bin common to all its fellows, eating the fruit of the common labor, sharing the common problems and tasks and suffering the common perils, but reaping the protection afforded by the combined strength of the colony.

Social animals ourselves, we are so familiar with these ways that we find it difficult to realize that very few other organisms are similarly social. Some kinds of birds gather in flocks, some mammals travel in herds, and many fish live in schools. But all of these are temporary gatherings, and in none of them do the creatures share a common dwelling and food supply. Other than the human, and the anthropoid apes, the only highly socialized animals are certain insects, namely the social wasps, the social bees, the ants, and the termites.

Most animals never give any attention to their eggs after they are laid, and go away without waiting to meet their offspring; but social animals keep their young under the ancestral roof, and the whole colony joins in caring for them.

Division of Labor.—Another distinctive thing about a society is its division of the labor that is to be done. Each social individual, instead of assisting in each and every one of the colony labors, becomes a specialist, performing only certain tasks in which it may become especially proficient. In human society some of us become butchers, some of us bakers, and others of us candlestick-makers. The butcher depends upon the baker and the candlestick-maker to work for him as well as for themselves, and he in turn does the butchering for them all. That is the way it goes with all well-regulated societies.

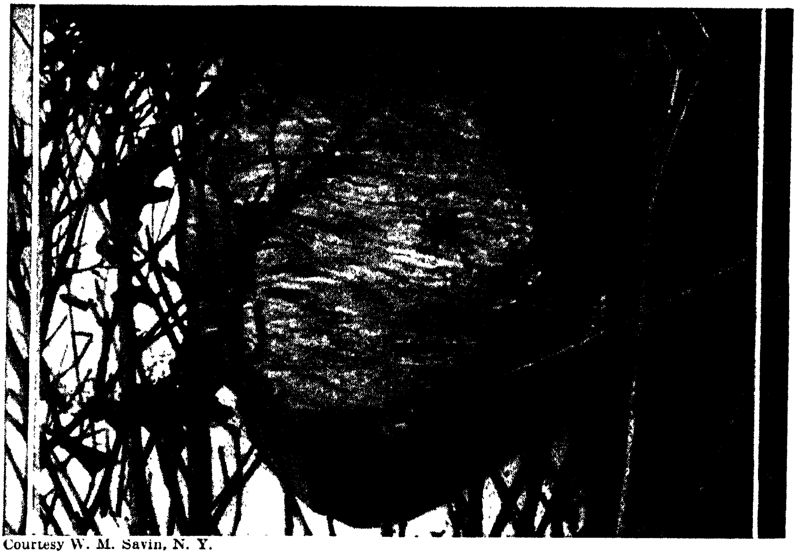


From Sladen. Courtesy Macmillan Co.

FIG. 416.—QUEEN ♀, WORKER AND DRONE ♂, BUMBLEBEES

Among social insects, the males and the females usually differ considerably in size and structure. The males usually have no duties but to fertilize the eggs, and with ants, bees, and wasps they are known as drones. Only among the termites are there worker males that share the hard labors of the colony.

The females of social insects assume two forms. The larger individuals are called queens, and ordinarily these are the only females that are capable of laying eggs. In starting the colony, the queen may perform prodigious labors; but after that, in many cases, she degenerates into an expert egg-laying machine,



Courtesy W. M. Savin, N. Y.

FIG. 417.—THE NEST OF A PAPER WASP

Courtesy W. M. Savin, N. Y.

FIG. 418.—INTERIOR OF THE WASP'S NEST

engaging in none of the other doings of the colony, and depending upon the other members of her queendom for her food. No insect colony ever has more than a very few queens, and often it depends upon a single queen.

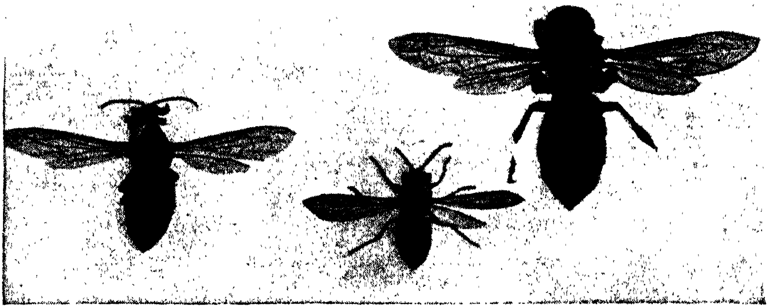
The other females of an insect society, and they are always very numerous, are sexually undeveloped and incapable of laying eggs. They are the workers. They build the social home, they keep it in order, they gather the food, they engage in battle with enemies that threaten the colony, and they generally perform all of the labors except those connected with reproduction. Sometimes there is a division of labor among the workers themselves, as we shall see in considering the several groups of insects that are social.

Social Wasps

There are many kinds of wasps, classified in a number of different families. All of the wasps that are social belong to a single group known as the social or paper wasps. The smaller species of this family are popularly known as hornets or yellow-jackets, while the larger ones are usually known as just plain wasps. Their large, paper nests, made from a mixture of chewed wood pulp and saliva, are familiar objects often found fastened to the branches of trees and hung from the rafters of buildings; and their smaller paper nests are common in bushes and in lower places. Often they are protected from bad weather by being located underground in natural cavities which the insects may enlarge.

Founding the Colony.—The wasp colony begins each year as a single individual, a young queen. She overwintered in loose soil or in some old log that was half rotted into the ground. Awakening now, this springtime, she sets to work building a very small nest containing a few paper-walled chambers in which she may lay her eggs. When the worm-like larvæ hatch from these, she feeds them, and soon raises a brood of small but adult workers.

These individuals immediately relieve their mother of all the labors of the colony except egg-laying. As the colony expands they may enlarge the original nest, chewing up wood pulp, mixing it with saliva, working it with their jaws and legs into thin sheets of paper, and building layer upon layer of remarkably tough and weather-proof walls. The more protected underground nests do not require so many layers of paper as the nests above ground; but in either case several layers of paper, with air spaces between, will help prevent too rapid temperature changes inside the nest.



Courtesy Conn. Agric. Exp. Sta.

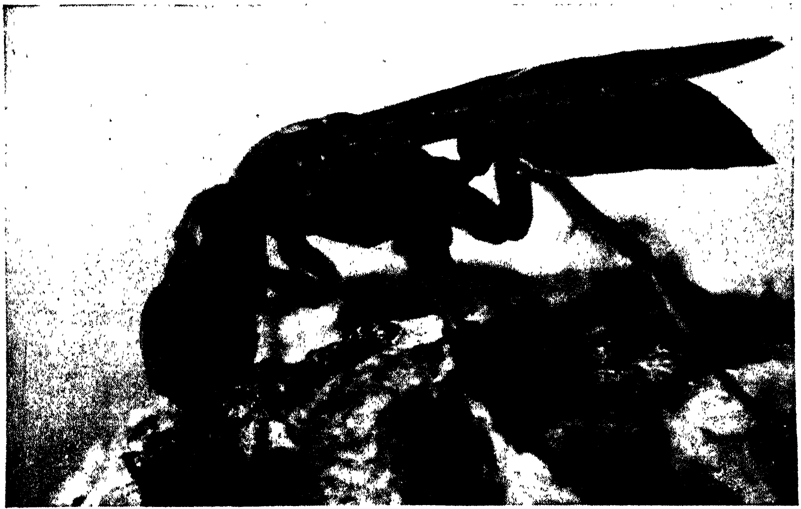
FIG. 419.—SOCIAL WASPS
White-faced hornet, yellow-jacket, and giant hornet.

The space within the nest is mostly filled with a comb, consisting of several scores of small, paper cells packed together in a layer that is always hung upside down. Additional combs are hung from the older ones by slender, paper ropes. The queen lays her eggs into the cells of the comb, and the larval wasps are kept in these inverted cradles.

Care of Young.—The worker wasps feed the babies on bits of chewed-up flies and other insects until finally the youngsters spin thin, silken cocoons for themselves, letting the tops of the cases protrude from the cells. In the privacy of the silken chambers they change their larval clothes for those of pupæ, and their pupal garments for the full armor of adult wasps.

Wasps never accumulate stores of food in their nests. What they feed the larvæ is brought in day by day; and they themselves eat while away from their nests, drinking nectar from flowers, titbits from our kitchens, broths from garbage pails, and strong drinks from over-ripe fruits.

At night the adult insects sleep inside their nests, or outside under the protection of some leaf or a cluster of flowers.



Courtesy P. G. Howes, from Insect Behavior, Badger Publ.

FIG. 420.—PAPER WASP ADDING WOOD PULP TO ITS NEST

It is not until late in the year that the queen lays the first eggs which develop into sexually mature wasps, that is, into new queens and into drones. At that season the colony becomes very large, and it may contain 4,000 or more individuals.

Soon after mating the young queens dig into the ground and prepare for their winter sleep. The rest of the colony then dies, and the storms of winter find only an abandoned nest on which to work their vengeance.

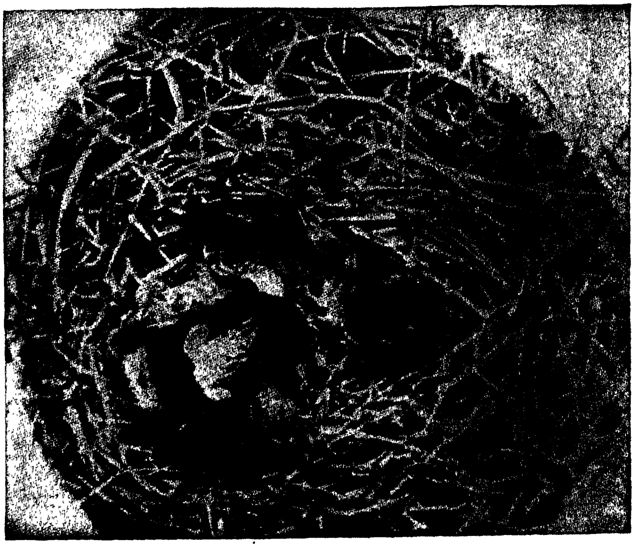
They are new colonies that the new queens bring into existence in the next springtime.

Bumblebees

If you have met these large, heavy-bodied, hairy insects only as they were seeking nectar in their visits to the flowers, you have not guessed what drama there is in the home-life of the insect.

For of all industrious mothers, insect or vertebrate, few will compare with the queen bumblebee.

Founding the Colony.—She also starts her colony in the springtime, usually locating in some old mouse hole for which she may have laboriously searched for days or even weeks. Near the center of this nest, which may be some inches, perhaps twenty feet or more from the entrance to the hole, she hollows out a snug chamber that is about an inch in diameter. On the floor of the cozy den she constructs a small waxen cell



From Sladen. Courtesy Macmillan Co.

FIG. 421.—A QUEEN BUMBLEBEE INCUBATING HER BROOD

Showing the honey pot in front.

which she partly fills with pollen gathered from the flowers of the field. On top of this she lays a batch of a half dozen eggs, and then closes the cell.

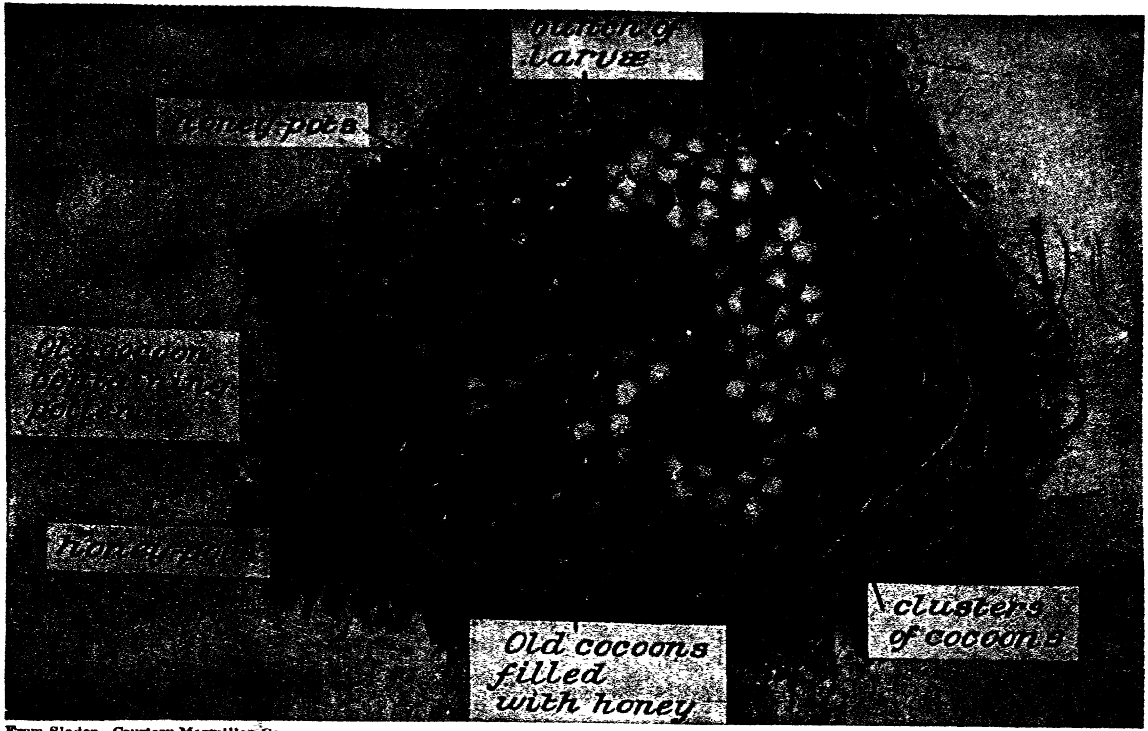
Care of Young.—The development of the young bumblebees now depends upon a properly constant degree of warmth, and the mother insect sets to work to incubate her brood as deliberately as though she were a hen.

In order to have food available without having to leave her eggs, she constructs a waxen pot that will hold about a thimbleful of honey and places this at the entrance to the brood chamber. When this food supply is exhausted she replenishes it by making a hurried trip outside. Within a few hours the pot is full again, and she may spend the rest of the day incubating the eggs.

The eggs hatch on the fourth day after they are laid. The queen keeps the larvæ covered with wax as long as she is caring for them, making additions to the swaddling clothes as the babies grow larger. The larvæ feed on the pollen and honey-paste bed on which they lie, but the queen may also feed them directly by breaking small holes through the wax coverings to the babies' mouths. Throughout the larval period the mother bumblebee spends much of her time brooding over her young, keeping them warm, and feeding them. In order to cover as much of the brood as possible, she may stretch her abdomen to twice its ordinary length.

Within a couple of weeks from the time that the eggs were laid, the larvæ are full-grown. Spinning thin, silken cocoons about themselves, they become pupæ, and after two weeks emerge as full-grown but very weak worker bumblebees. Tottering to the honey pot, they find food. Then they return to their mother, where they are kept warm for another day or two, when they become strong enough to go into the open for food, and to help with the work of the colony.

Throughout the rest of the summer, brood after brood of workers is reared by the mother bee, assisted now by her oldest



From Sladen. Courtesy Macmillan Co.

FIG. 422.—NEST AND COMB OF A BUMBLEBEE

Showing honey pots, masses of wax-covered larvæ, and clusters of cocoons.

daughters, who gather food and help take care of their baby sisters. In time the nest becomes as large, perhaps, as a man's head, and then it may contain a large number of honey pots. Many a boy knows the taste of the honey, though few know of the labors of the mother whose honey pots they are robbing.

A colony of bumblebees is, then, a household of a single mother and her infertile daughters. The fertile daughters and the sons are not hatched until later in the season. The young males leave the nest as soon as they are able to fly, and soon (July-September) mate with the young queens.

The fertilized queens burrow into loose soil, and, taking along a bit of honey to sip, they go to bed for a long sleep that will last for the seven or eight months of the fall and the winter, and end only with the springtime. Then the young queens will start their own households.

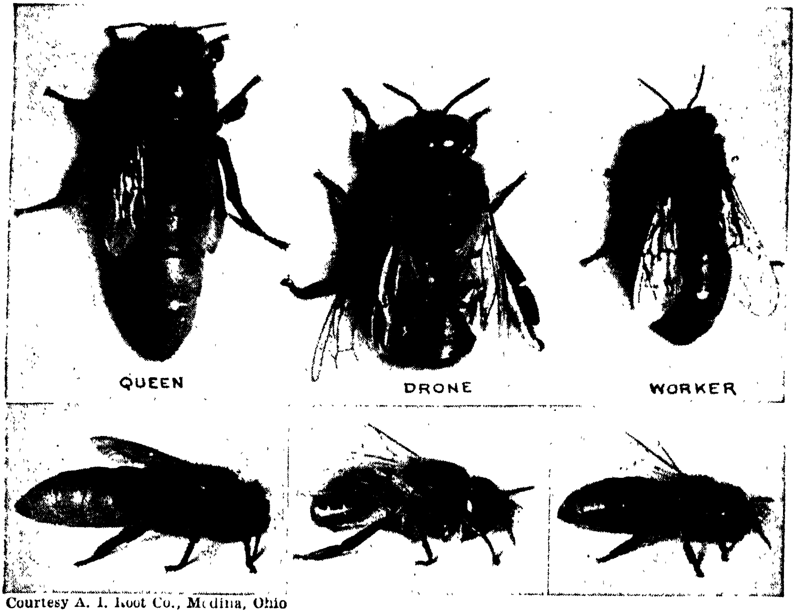
The old colony lives along for a while after the mating season, but in time the workers begin to die, the queen stops laying eggs, and finally, some night, she too grows drowsy and falls asleep. But she will never awaken. The big household has run its course, outlived by only the young queens that will mother next year's colonies.

Parasitic Bumblebees.—Among the many intruders that would upset the peaceful course of the bumblebee colony, we must mention the strange usurper that dresses in the clothes of a bumblebee, although it belongs to a species that has no workers and that, therefore, has to depend upon the labors of industrious insects. These dishonest females are to be seen often enough in the fields. They are easily distinguished by their hairy legs which lack the smooth areas that form the pollen baskets of proper bees.

The false bumblebee finds her way into an honest bee's home, and although she is at first received with hostility, she in time becomes an accepted member of the colony. She then destroys the eggs which are laid by the queen mother of the establishment, lays her own eggs, and has them reared by the workers.

Honeybees

The honeybee, commonly kept in a sort of domestication by man, is a more perfectly social insect than any we have yet considered. Its colonies persist indefinitely for years at a time.



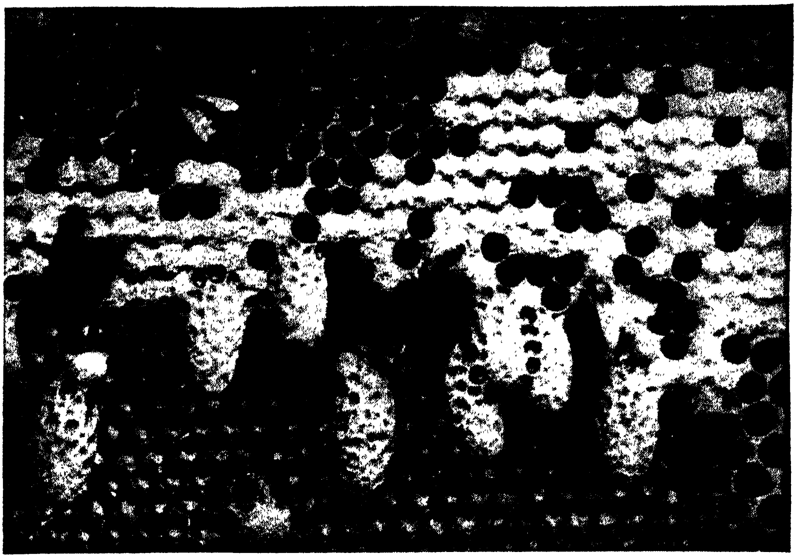
Courtesy A. I. Root Co., Medina, Ohio

FIG. 423.—HONEY BEE CASTES

Its adult workers and queens may live over the winter, depending upon the large quantities of food (honey) that may be stored in the nest. Although worker bees usually wear themselves out in the course of a few weeks of work, they may, under favorable conditions, live for many months; and queens may in some cases live for four or five years or even longer.

Queens.—There is rarely more than one queen in a honeybee nest, and she never does much else in her life besides lay eggs. She often lays as many as two thousand eggs a day, and may lay more. She has nothing to do with the care of the eggs and of the larvæ. If a second queen gets into a hive, the old queen usually kills her, or one or the other is forced to leave. A colony left without a queen loses interest in life and soon dies out.

Workers.—The worker bees divide the labors of the hive. Some of them gather the food, which is pollen and nectar taken from flowers. The nectar is brought back in the honey stomachs (located between the mouths and the true stomachs) of the insects. It is regurgitated into the cells of the wax comb of the hive; but since it contains too much water to preserve well, certain bees station themselves, head down and wings a-buzz, where they may fan the liquid for hours at a time until most of the water is evaporated. As a result of this removal of water, chemical changes then occur in the material and it becomes *honey*, ready to be sealed up in the cells.



Courtesy Dr. E. F. Bigelow

FIG. 424.—PART OF A HONEYBEE COMB

Drone cells (lower right corner), worker cells (some with caps), and queen cells (shaped like peanuts).

The wax from which the comb is built comes from the bodies of the workers. These bees prepare for their labors by eating large amounts of honey, and then gather in clusters so the heat of their bodies may raise the temperature very considerably. After some hours, perhaps not until after a day or two, a liquid secretion oozes forth on the under surfaces of the abdomens of these bees, and hardens into thin plates of wax. The wax is transferred to the comb and built into new cells.

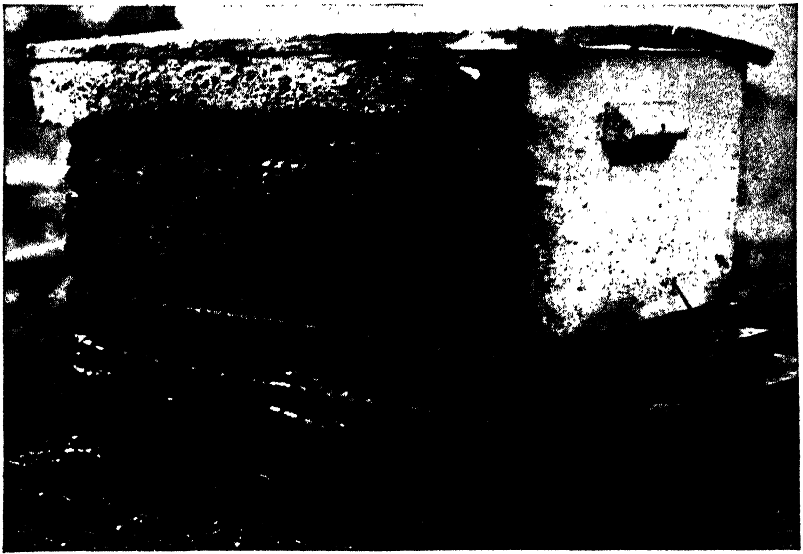
The structure of the comb is remarkable for its regularity. It consists of a double layer of cells so placed back to back that the partition serves as the common base for the two. Each cell is beautifully six-sided, which allows it to fit in advantageously with the surrounding cells. Most of the chambers are designed for the storage of honey, but others are used as cradles for the young bees.

The Babies.—The queen lays her eggs into the bottoms of empty cells, and in three days they hatch into tiny, legless, white grubs. Certain of the youngest workers are the nurse bees. At first they feed the babies on bee-jelly, a material which is digested in the bodies of the nurses before it is regurgitated into the mouths of the young larvæ. Later the larvæ are fed on pollen and honey taken out of storage by the nurses.

After five and one-half days the babies, having become well-grown, are put to bed in the cells, which are then sealed over with wax. Each larva in time becomes a pupa, and in another twelve days it has completely changed into an adult bee. Then it chews its way out of its cell. In the hive it takes its turn as a nurse, remaining at that service upward of two weeks before it goes into the fields to become a gatherer of pollen and nectar.

Caring for the Hive.—Other workers in the colony have still other duties besides those already mentioned. Some of them remain as guards at the opening of the hive, forbidding entrance to all but the acceptable members of the colony. Some of the workers collect waste materials that may be dropped in the hive, and carry them out-of-doors. Others repair broken brood and food cells. Some workers feed the queen and the drones. Still others arrange themselves in a line leading from the front door to the interior of the hive, and by the long beating of their wings the air of the hive is moved enough to furnish really effective ventilation.

When it is cold out-of-doors, the insects may raise the temperature of the hive by clustering in a hollow ball, in the interior of which a number of bees exercise vigorously and thereby develop considerable heat. So effective is this method of heat production that the temperature inside the cluster may be as much as 75° F. higher than the temperature a few inches away from the cluster.



Courtesy A. I. Root Co., Medina, Ohio

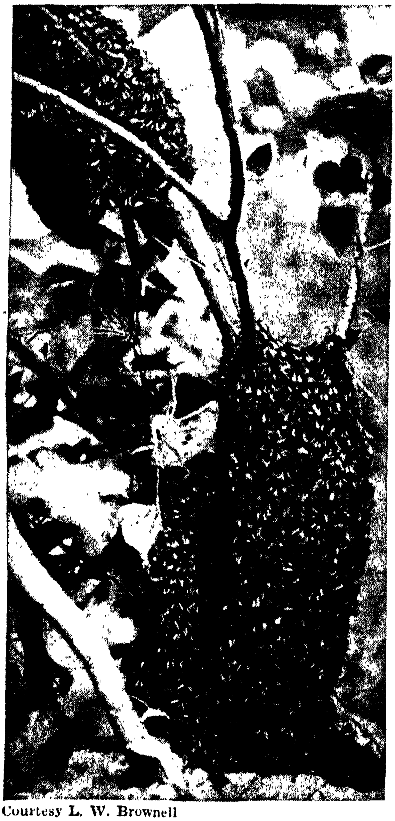
FIG. 425.—THIS HIVE NEARLY BURNED IN A LUMBER-YARD FIRE

But by beating their wings, the bees kept the interior cool enough to prevent the melting of the wax comb.

A prosperous honeybee colony may number 60,000 or more individuals in the summer. It will drop to 10,000 in the winter, when it must live on stored food. Normally none of the males are allowed to survive at that season. The workers, who ordinarily feed the drones, first starve them, and finally carry them out and drop them at some distance from the hive.

New Colonies. — Whenever a honeybee community becomes too large, the bees build a giant wax cell, and the larva that develops in this cradle is fed on nothing but bee-jelly from the mouths of the nurses. This exclusive diet is apparently responsible for the fact that this individual develops into a mature queen.

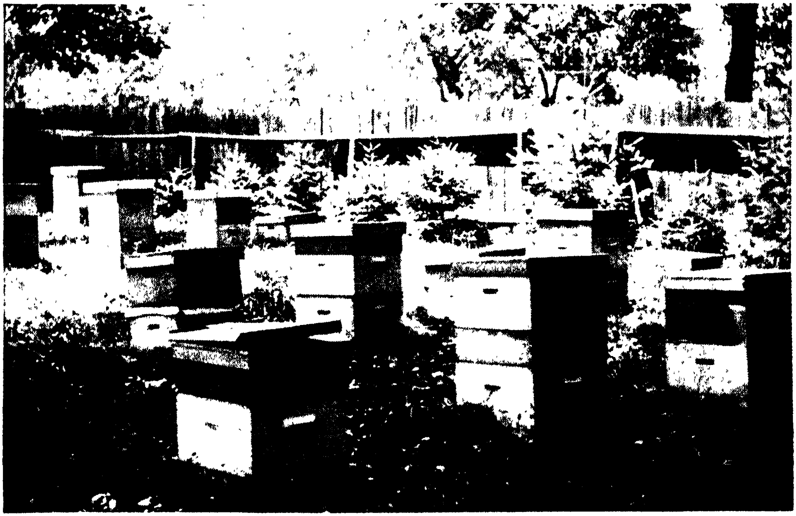
Now, the old queen, with her authority endangered, would sting her daughter to death if the workers didn't cluster around their mother in such numbers as to interfere with her plans. In the excitement of these times, the old queen finally sets forth from her home, accompanied by some thousands of her daughters, and flies away, swarming, as we say, to some other locality; and there she may set up her housekeeping anew.


Courtesy L. W. Brownell
FIG. 426.—HONEYBEES SWARMING

A few days after the new queen has become mistress in the ancestral colony, she ventures out to engage in the remarkable mating flight which we have already described (Chapter XIV).

Bee-Keeping.—The wild honeybees nested in cavities such as are to be found in hollow trunks, but since earliest history man has provided nesting places so fixed that he too might share the honey gathered by the industrious insects. There are no native honeybees in this country, although colonies may sometimes escape from their owners and swarm to the woods.

The bee-keeper provides his bees with a hive that is designed to reduce the labors of the insects. He provides some of the wax which they use for the comb; he sees to it that they have sufficient sources of food; he prevents swarming or directs their swarms into new hives; and he helps protect the colony against enemies, severe weather, and disease. In return he takes part of the superabundant supply of honey which is stored in a healthy hive.



Courtesy Ind. State Entomologist's Office

FIG. 427.—HOMES PROVIDED BY THE BEEKEEPER

Incidentally, in working with his bees the bee-keeper has the opportunity to observe at first hand the remarkable behavior of these interesting insects.

For although we shall have to explain all of the activities of the social wasps and bees as reflexes, tropisms, instincts, or memory behavior, and not as the results of reasoning intelligence, it remains an astounding fact that these tiny creatures live together in complex, social relations in which they labor for the colony rather than for their individual benefits.

SUMMARY

1. Social animals live in colonies consisting of individuals of both sexes and of all ages, both adults and young. They share a common roof, contribute to a common store of food, and provide mutual protection.
2. The only highly socialized animals are man, the social wasps, bumblebees, honeybees, ants, and termites. As social animals, we are particularly interested in these other social species.
3. In a true social colony there is always a division of labor. Among social insects, the males and females differ considerably in structure, and there may be a number of different forms of females (and, among termites, of males). Each of these several forms is built for performing particular tasks.
4. The social wasps (hornets, yellow-jackets, wasps, etc.) live in paper-covered nests established by a single queen. The young are fed on insect food brought in by the adults. No food is stored. The colony may expand to 4,000 by the end of the season. It dies on the approach of winter, only the young queens burying themselves in the ground and living through until the next spring.
5. The bumblebee mother is a model of industry and devotion. Alone, she starts the colony in the spring, building the nest, incubating the eggs and young as carefully as a hen, gathering food, and feeding her offspring. As the colony grows, the newly matured workers help. The colony dies off in the fall, only the new queens overwintering in the ground.
6. Parasitic bumblebees, that have no workers and hence cannot establish a colony of their own, sometimes enter bumblebees' nests, destroy the rightful queen's eggs, and make her workers work for them.
7. Honeybee colonies live on from year to year, both the workers and the queens overwintering inside the hive, the drones usually perishing at the approach of winter. The single queen in the colony is concerned with nothing but egg-laying.
8. The worker honeybees divide the labors of gathering pollen and nectar, making honey, making the wax comb, caring for the young, guarding the entrance, cleaning the hive, feeding the queen and drones, and ventilating the hive. In cold weather clusters of active bees may

raise the temperature as much as 75° F. When young queens are raised in the hive, the old queen leaves, "swarming" with part of the old colony. Since before earliest history man has been providing homes, part of the wax hive, and other aids to these insects.

DEFINE

Social animal
Drone
Queen (insect)
Worker (insect)
Honey
Swarm (of bees)

PROBLEMS

1. How many different people helped in getting the food for your breakfast?
2. How many individuals help such a non-social animal as a frog or toad get its breakfast?
3. What resemblances do you see between the life processes of a plant and the life of a colony of social animals?
4. Have you ever seen the nest of a social wasp, a bumblebee, or a honeybee? Where? Describe it.
5. What do you consider the most interesting single behavior of the social wasps? the bumblebees? the honeybees?
6. Which is most social, and which least so: the bumblebee, honeybee, or social wasp? In what ways?
7. If you should find live honeybees in February, would you expect them to be drones, workers, or queens? If you found live bumblebees? And live social wasps?
8. Name six ways in which the behavior and social life of the honeybee differ from those of the bumblebee.
9. Is it possible for a man to live without using any of the things that other human individuals ("society") provide him? Did Robinson Crusoe do it?
10. Is a specialist or a jack-of-all-trades more valuable to present-day society?
11. What are the advantages and disadvantages of being a specialist, and in being a jack-of-all-trades?
12. Workers and queen honey bees develop from fertilized eggs, but the drones come from eggs that grow without being fertilized. How many genes are in each cell of the body of a honey bee queen? A worker? A drone?
13. What unusual difference must there be between the maturing of a honey bee egg and a honey bee sperm?

CHAPTER XLII

ANTS AND TERMITES

Let us turn over some of the shallow stones that are to be found in the fields and the woodlands. There will be ants under many of them. If we watch the insects closely, we shall see some surprising things.

The Castes

Here! There are several forms of ants living in this colony that we have uncovered. Most of the individuals are small and wingless workers, but there are some drones that are a bit larger and oftentimes winged, and there are a few winged queens that are several times the size of the other ants. All of these forms are castes of the one species of ant that has established its home under this stone.

Queens.—These queens are probably young ones, for the old queens live much deeper in the ground. They are very busy down there, laying eggs. They are long-lived individuals. One queen is known to have lived fifteen years. There may be several functioning queens in an ant colony, or there may be only a single one.

The young, virgin queens have only recently come out of their pupal cocoons, and they are now (late spring) crowding to the surface. Soon they are going to test their wings in a mating flight that much resembles what we have already described for the honeybee. You have probably seen the mating flights of winged ants in the late spring and early summer, though you may not have realized what they were about. After the mating is over, the young queens will come down to the earth, rub off their wings, and dig into the ground to start new colonies.

Workers.—Most of the individuals of an ant colony are infertile females of the worker caste. They always lack wings. There may be several forms of these workers in a single ant nest. There may be large-bodied, large-headed individuals that are well fitted for fighting. You can easily see these soldiers among the big, black carpenter ants found in decaying stumps. The smaller workers act as the nurses of the young ants, as

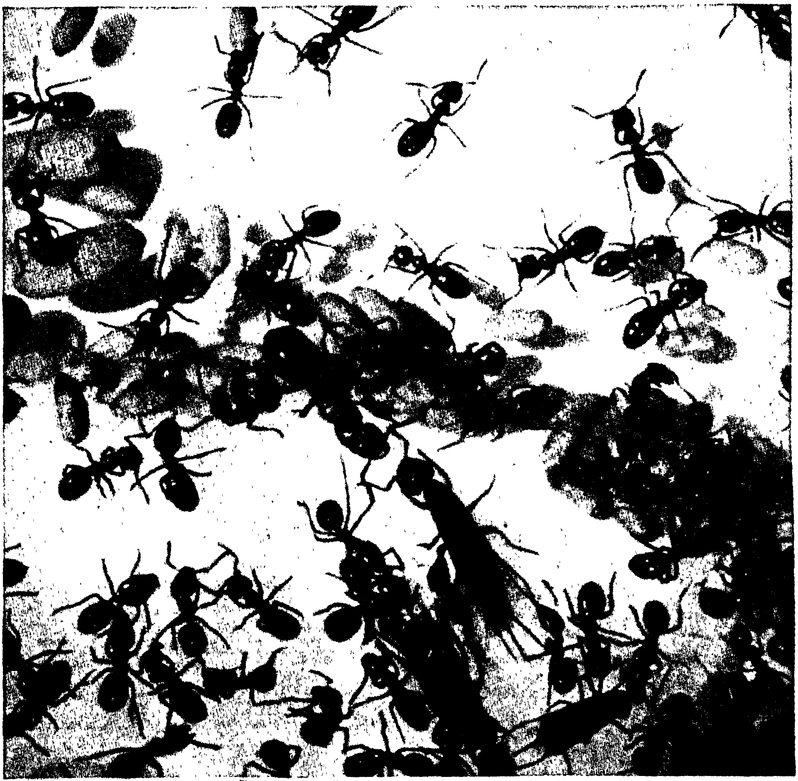


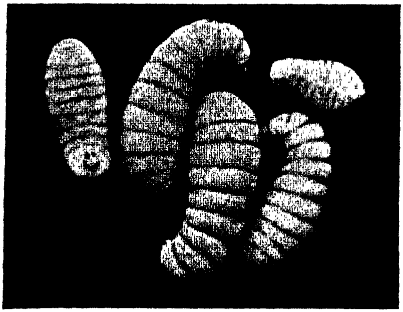
Photo by Hubbard and Strong. Courtesy W. M. Wheeler

FIG. 428.—THE ANT COLONY UNDER THE STONE
Showing workers, young queens, and cocoons.

housekeepers tidying up the home, as carpenters and as engineers making additions to the nest, or as farmers and hunters and merchantmen gathering the food for the colony. Worker ants may live three or four years, or longer.

Eggs, Larvæ, Pupæ.—The eggs of ants are tiny, pearly things usually not so large as a pin-head. You may find them sometimes stuck together into clusters that are convenient for the workers to carry about.

When an ant hatches from an egg it is a tiny, whitish, grub-like larva that can move very little, and has to be cared for by its grown-up sisters and aunts. Ant pupæ may or may not have cocoons covering them. Ant cocoons are often conspicuous under shallow stones, and they are often mistakenly called eggs, although they are, of course, very different things.



Courtesy W. M. Wheeler

FIG. 429.—ANT LARVÆ

No other business of the colony demands such attention as the workers bestow on these eggs, larvæ, and pupæ. They carry them about from place to place in the nest to keep them where the temperature and moisture conditions are just right. Each morning they carry them from the lower galleries to the upper levels where they will be warmed by the sun; and if it should rain or become too cold or too hot during the day the workers will carry their wards back to the interior of the nest.

The workers of some species place bits of food directly into the mouths of the larvæ. This food may have been partly digested in the mouths or the crops of the nurses before it was regurgitated for the baby. The nurses continually lick the bodies of the larvæ, keeping them free of mould and dirt and refuse, and incidentally finding a reward in the fatty secretions of the larval skin. When danger threatens the colony, the adult workers usually give first attention to guarding the younger ants. Did you notice how the workers hurried to carry the larvæ and cocoons to cover when we turned the stone from this nest? And did you see how very quickly those things disappeared?

Ant Nests

Most ants nest in the ground. Using their jaws and less often their legs, they dig out innumerable tunnels, passageways, and chambers, until the earth becomes honey-combed with the structures.

The nest provides a considerable protection from such enemies as birds, mice, and predaceous insects. The nest remains relatively dry in all but the heavier rain storms. In its deepest parts the temperature does not change so greatly as nearer the surface. Seeds and other materials may be safely kept for many months in a deep nest.

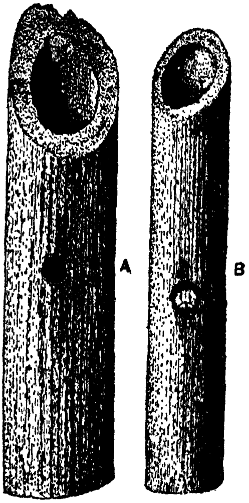
Some ant nests have only a single entrance, and tunnels that extend for only a few inches. Other nests may be several feet in diameter, and extend as far into the ground. Most of the colonies are located under thin stones, chiefly for protection, but also because the stone gathers the heat of the mid-day sun and keeps the nest from cooling too rapidly at night. You need not attempt to find nests beneath large, deeply buried stones for they do not warm through enough to attract ants.

Mound Ants.—The mound-building ants may pile dirt and bits of plant material for several feet above the surface of the ground. The thatching ant of Colorado accumulates quantities of long grasses and other plant stems in its mound. A prodigious amount of labor with tiny legs and jaws is necessary to erect such a structure. The mounds are honey-combed with passages, quite like the rest of the nest. As the plant material in such a mound slowly decays, its temperature may become ten to twenty degrees warmer than the surrounding air; and the mound becomes a sort of incubator in which the young ants develop.

regularly removed to one side of the nest where a sort of trash and garbage heap is maintained. While they are unable to carry out such obnoxious materials as oils and some strongly odorous substances, they cover them with earth and bury the nuisances.

During a bright day the nests have their many entrances open. Then the underground passages become well ventilated and dried out. Workers, perhaps soldiers, may stand near the portals to keep out intruders. The soldiers of certain species block the entrances with their large heads, sitting solemnly for hours as living door-posts, moving aside only when the rightful members of the colony seek admission.

At night the doorways are mostly filled with earth. So they are in cold and rainy weather, but if you gently disturb a mound ant's nest at such a time you may see the doors flung open and the colony surge forth to do battle.



Courtesy W. M. Wheeler, Harvard Univ.

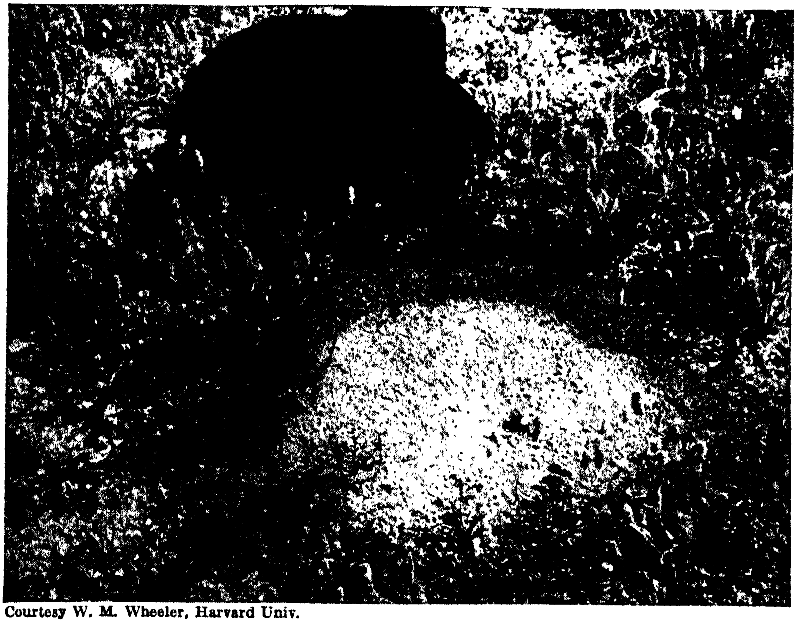
FIG. 433.—A LIVING PORTAL

Soldier of a stem-inhabiting ant blocking the entrance to the nest in B.

Colonies of ants may hold together for as long as thirty or forty years, even though the individual ants die as new generations come on, and the nest continually enlarges and changes. Large mound nests may contain 100,000 ants, although 2,000 would be nearer the population of the average colony.

Ant Vegetarians

Most ants utilize a great variety of things as food, and that helps them to get along under many different conditions. The primitive ants were carnivorous species, feeding upon animal materials; but today most ants include at least some vegetable foods in their diets. For that matter, no animal can go very far in becoming social until it has learned to use plant foods, for such things are stored more easily than animal stuffs, and they may be depended upon as winter provisions.



Courtesy W. M. Wheeler, Harvard Univ.

FIG. 434.—NEST OF A HARVESTING ANT, ARIZONA
Showing chaff cast in a circle about the nest.

Harvester Ants.—Many ants gather the seeds of plants along with their other provisions. The harvester ants of Texas and our Southwest depend largely upon such seeds. They carefully remove the seed coverings and cart away the chaff, dry the grains in the upper galleries of their nests, and then store them where they will be least liable to become wet. When heavy rains do reach their stores, they carry the seeds out and expose them to the sun and air. Spoiled seeds are scattered away from the nest, and an occasional one of these grows, giving rise to the unwarranted notion that the ants even sow the grains which they are going to harvest. The hard-coated seeds gathered by these ants are more easily crushed by the large-headed soldiers, who thus become "the official nutcrackers" for the whole colony.

Leaf-Cutter Ants.—Certain other vegetarians are the leaf-cutter ants, common in Texas and the Southwest. A related species that gathers plant debris occurs as far north as Long Island. The southern species cut semicircular or triangular pieces out of the leaves of shrubs and other plants. Snip, snip, snip, you may hear their clicking jaws, and in a few minutes each ant has bitten out a piece of leaf two or three times as large as itself. Holding its trophy over its head like a banner, the ant joins the endless ranks of its fellows that are marching on the ground.

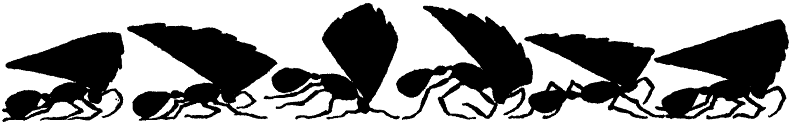
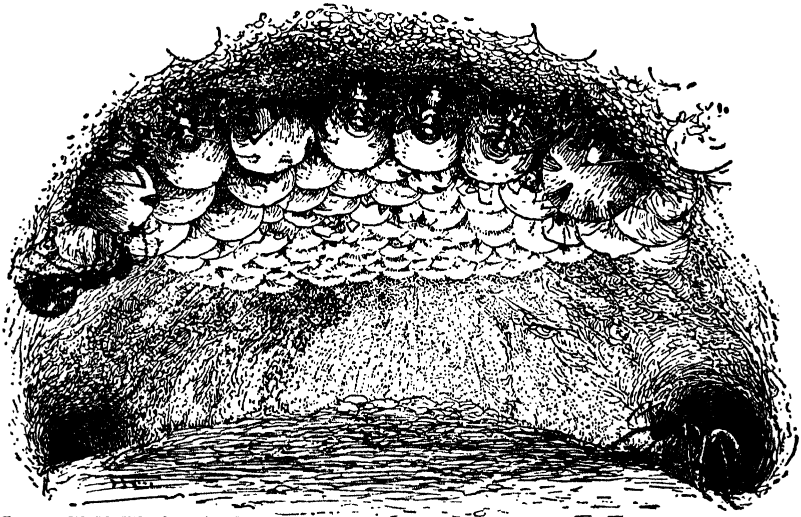

M. L. Voorhees, Del.

FIG. 435.—LEAF-CUTTER ANTS

Perhaps you think they are going to use these bits of leaves as food. That, strange to say, is not why they cut leaves. Could you follow one of these ants into its nest, you would find, down beneath the surface, that the leaves are packed into a moist room to decay, and that certain very small, almost blind workers spend their whole lives in these chambers wetting the leaf material with their excrement. There are some species that bring in caterpillar excrement in place of leaves.

This decayed material, you see, provides just the proper soil for fungus gardens. And mushrooms are the food of the leaf-cutters! When the queen first started this nest, she carried in her mouth a bit of the particular kind of fungus which was raised by the colony in which she was born, and from that beginning have come the several fungus masses in the present nest. Some of these masses may be as large as a man's head. The gardens are carefully trimmed and kept in condition for supplying actively growing food to the ants.

Honey Ants.—In the Southwest, from Texas to California, and in the Pine Barrens of New Jersey and the other northeastern states, there are ants which live upon a honey-like plant secretion, obtainable from a variety of sources. Many kinds of oak galls, for instance, are covered with such sticky secretions when they first begin developing. The honey ants gather this material, but they are confronted with the problem of storing it.



Courtesy W. M. Wheeler, after McCook

FIG. 436.—LIVING HONEY POTS
Hanging from the roof of a honey chamber.

For honey is not easily kept from spoiling and it cannot be piled on the floors of an earthen nest to keep over winter. Therefore, certain workers of each colony offer themselves as living jugs, drinking all of the honey as it is brought in, and storing it in their crops until their abdomens, in the course of

23

three or four weeks, become tremendously swollen. These honey pots hang on the roofs of the chambers through the winter, or even for years. When their fellows need food they regurgitate their honey a bit at a time. It is a remarkably successful way of preserving a perishable food supply.

Courtesy W. M. Wheeler and Amer. Mus. Nat. Hist.

FIG. 437.—ARMY OF DRIVER ANTS CROSSING A DITCH, EAST AFRICA

Relations with Other Animals

Army Ants.—The outstanding head-hunters among the ants are the large-bodied driver or army ants found in the tropics of both America and Africa. These build no permanent nests, but travel about in tremendous armies. They are almost blind and wingless, but their keen sense of smell leads them into every corner of the jungle, where they attack other insects and birds and beasts in such overwhelming numbers that few things can escape. Even boa constrictors are said to be torn to pieces, bit by bit, by the jaws of these terrible insects. Clambering over the trees, the ants mass in living chains, which hang from the branches to the ground. Living bridges are in a similar fashion formed across the small streams which are encountered in the marches.

None of our North American ants are as active hunters as these drivers, although many of our species capture other insects and even larger animals. Many ants raid nests of other ants, chiefly for the sake of capturing their pupæ for food; and as an incidental result of this some of our ants have become slave-makers.

Courtesy M. W. Wheeler and Amer. Mus. Nat. Hist.

FIG. 438.—DRIVER ANTS CROSSING AN OPEN PATH, EAST AFRICA
The soldiers form two solid walls, lifting and opening their jaws; the workers with the young pass between the rows of soldiers.

Slave-Makers.—One of these slave-makers[1] rather commonly nests under stones and in mounds in the northeastern states, and elsewhere in this country. The species is a fighter, and if you disturb its nest it will swarm over your hands, biting with its jaws and spraying a poison from the tip of its abdomen into the wound (as many ants do). This species often raids other ant nests. Some time before such a raid, scouts locate the city to be invaded, and fix the paths to it. When the raid starts, hundreds and thousands of the warriors swarm to the venture. Sometimes they may go a hundred yards or more in their attack.

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[1] It is of moderate size, with a mostly blood-red head and thorax, and a black abdomen.

Waiting their chance, they pour into the passages of the nest and snatch up the pupæ or cocoons. About the doorways of the colony the defenders engage in innumerable little encounters with the invaders, but the latter are not warriors as much as kidnapers, and as quickly as possible they withdraw with their plunder. It is quite possible that some of the booty is eaten, but most of the stolen babies become adopted members of the new family, and are raised to maturity as carefully as the slave-maker's own offspring. These imported individuals then engage in all the ordinary work of the colony, and in that sense are slaves.

Still other slave-makers, more rare in this country, are the Amazon ants, whose sickle-shaped jaws are deadly weapons in battle, but inconvenient tools for handling foods. Consequently these ants are well able to secure slaves, but they cannot feed themselves, and the slaves have to place food in the mouths of their mistresses.

Other Occupations.—Ant societies also include tiny thief ants that live in very small tunnels that communicate with the passages of some larger ant's nest. The big ants cannot get into the tiny tunnels to punish the thieves, but the tiny ants can slip out when the coast is clear and rob the mansion of its treasures.

There are certain small ants that are welcomed in other ant nests because, when enemies attack, they form an advance army which keeps the intruder busy until the ranks of the larger ant can be brought into action.

There are other ant guests which are welcomed because they are shampoo experts that spend their time licking the bodies of their hosts (for the oily secretions on them), and the hosts are much attracted by such attention.

Courtesy P. G. Howes, from Insect Behavior, Badger Publ.

FIG. 439.—ANTS TENDING THEIR PLANT LOUSE COWS

There are guest ants that prove traitors and murderers. One of the largest of the common red-and-black ants found in mounds in the northeastern quarter of the United States is such a traitor guest. It invades the mound of a rather smaller black ant, where it is received peacefully enough. But in time the red ant queen replaces the queen of the black ants. From then on the only eggs that are laid grow into red ants, who thus reap the benefit of the labors of the black species. You may find both black and red ants in such a mound, unless the rightful owners, the black ants, have completely died out.

Ant Cows.—Less tragically clever are those ants that are herdsmen. Their cows are the tiny, green or black plant lice (aphids) which commonly cluster on stems and leaves and suck the juices of the plants through their slender beaks. Young black poplar trees are often loaded with plant lice. Chrysanthemums and the young shoots of rose bushes are often so afflicted. If you examine such plants, you are likely to see ants running among the plant lice, stroking them with their antennæ, and causing them to excrete tiny drops of a sweet, liquid excrement which the ants drink with evident delight. A few minutes of close watching of these ants will allow you to see all of this remarkable performance.

Not only do the ants feed upon the plant louse excretions, but they bestow on the little insects something of the care that a farmer might give his herd of milk cows. When food becomes scarce for the lice, the ants pick them up and transport them to better feeding grounds. When winter approaches, the ants gather the eggs of the plant lice, carry them to the safety of their own nests, and care for them until they hatch in the early springtime. Then columns of louse-laden ants may be seen ascending the budding trees, putting their stock out to pasture. Some ants even build leaf and paper coverings over the parts of the plants where the aphids are feeding, making sorts of cow sheds for the miniature cattle.

Some other plant lice and certain scale insects secrete a waxy material of which ants are very fond. This is the ant chewing-gum factory, if you please. The small, light-yellow ants commonly found under thin stones live perpetually in the ground (they are almost blind), and they feed from such waxy-coated or honey-dew secreting plant lice located on roots. In the Middle West one such species of yellow ant places so many plant lice on the roots of corn as to be the indirect cause of a great economic loss.

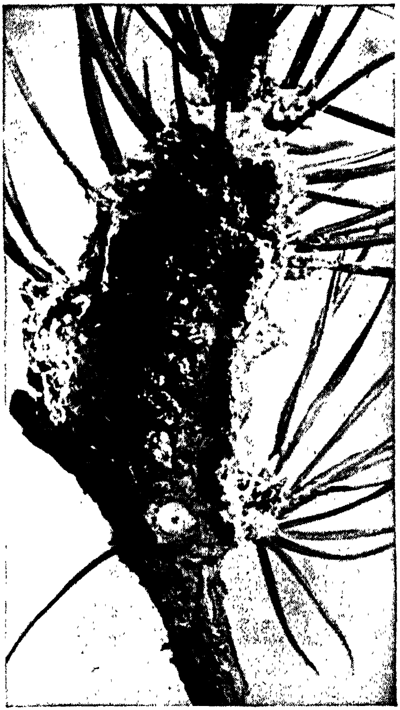

Courtesy W. M. Wheeler, Harvard Univ.

FIG. 440.—PAPER TENT BUILT BY ANTS

Cut open to show the scale insects which the ants were tending.

Termites

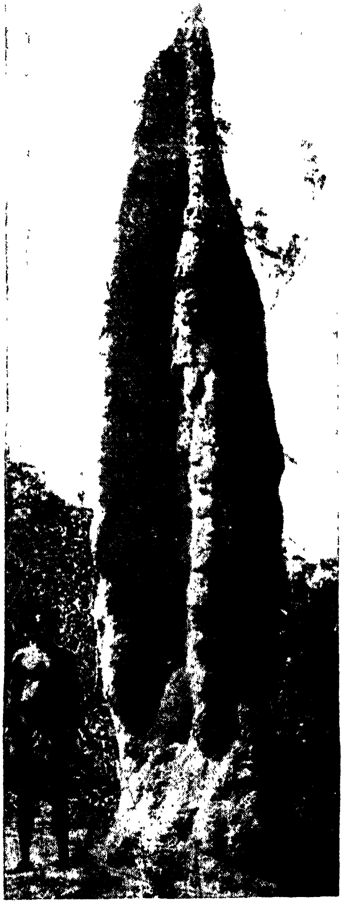
The termites, or so-called white ants, superficially resemble the true ants and live in similar social organizations. But they are not at all related to the true ants and should be given their more distinctive name.

You have probably seen winged swarms of these insects in the early spring, issuing from some telegraph pole or a beam in your cellar or some other piece of decaying wood. For termites are wood-feeders. Outside of the mating swarms, termites are rarely seen. During the rest of the year they shun the light; and they work only in wood which is constantly moist; and though they may be reducing a beam to a mere paper-thin shell their presence is not to be suspected until they swarm, or until some pressure on the damaged timber suddenly makes it go to pieces.

Termites are among the most abundant insects in the tropics, where their mounds may tower as high as twenty feet. The populations of such colonies may run into the millions. In these regions they do untold damage to property, destroying houses and all other structures which are not made of stone or metal. Termites do some damage in our own southern states, but northward they are less common and of less economic importance.

Termite colonies differ from those of the ants chiefly in having both female and male workers and soldiers and in having a king as well as a queen.

It is remarkable that two such different groups of insects as the ants and termites should resemble each other so closely in their social organizations. The termites even grow mushroom gardens as the ants do, and they entertain numerous other insects that provide food much as the plant lice do for the ants. Were we located in the tropics, we should want to study the termites in detail.



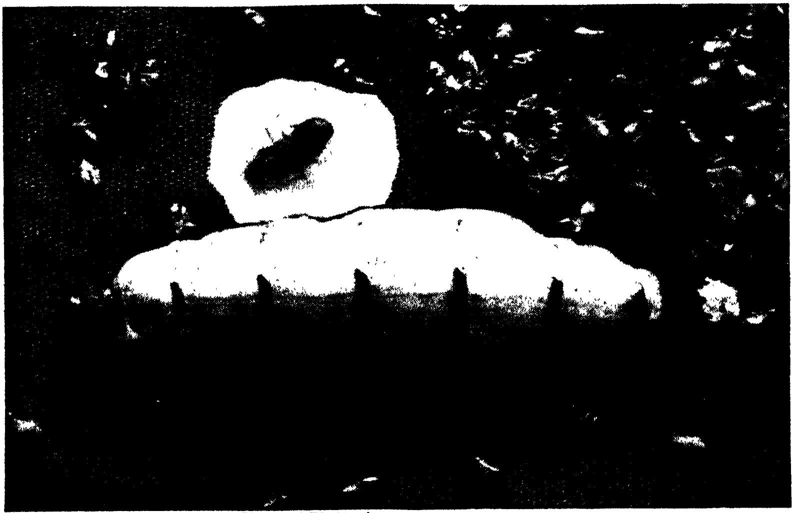
Courtesy W. W. Froggatt, Australia

FIG. 441.—NEST OF AN AUSTRALIAN TERMITE

Ant and Termite Behavior

It is almost inconceivable that ants and termites should do the things we have described. Similar behavior on the part of the human would ordinarily be credited, and probably correctly, to a high development of reasoning intelligence. But there is every reason for believing that ant and termite behavior is mostly mechanical, or the result of only simple intelligence.

Ant and termite colonies are kept together by the simple arrangement of having a common food supply at home. The members of the colony that are especially equipped for particular duties, as the ants that are the honey pots, or the tiny ants that manure the fungus gardens, or the shampoo experts and the plant louse cows, the slaves, and the other guests that may be admitted to the colony, are the natural objects of much attention because they are the sources of food.



Courtesy Prof. L. B. Uichanco, Univ. of Philippines

FIG. 442.—THE CASTES OF A TERMITE

Showing the queen (sausage-shaped), the king, soldiers, and many workers.

Even the care which the ants bestow on their young, and the regard in which they hold their queen mothers, may have originated as nothing more complex than a search for food, for the babies are covered with oily secretions of which the adults are very fond.

Ant Senses.—Many of these performances depend upon the remarkably keen sense of smell which ants possess. They not only distinguish food and other agreeable and disagreeable things, but they can recognize the members of their own colonies, even though they may number many thousands. It is a simple experiment to take ants from one colony to the nest of another, where they are recognized as not possessing the proper colony odor, and are sooner or later attacked and driven away or killed. Ants that have been away from their nests some days, or which have had the mishap to have had a bath while away, lose their colony odor and are received as strangers by their comrades. There is some evidence that ants may follow paths, which they or their companions have previously gone over, by means of this delicate sense of smell.

Taste and touch are similarly well-developed senses with these insects. Hearing and sight are not so keen.

It is possible, then, to explain many of the doings of ants as tropistic responses to chemical stimuli received through the taste and smell organs. Their discovery of hidden food supplies, their location of the nests they raid, their following of trails established by scouts, their use of such special foods as plant louse excretions and fungi, and their friendly bearing toward the other members of their colonies may be explained, in part, as such mechanical responses.

Instincts and Emotions.—Some of this behavior is so very complicated that it must be thought of as chains of activities, that is, as instincts.

Ants moreover appear to feel such emotions as accompany instinctive activities. They show anger or fear when they are attacked by other ants, pleasure when they locate their larvæ or a rich food supply, excitement when the usual program of the colony is disturbed, and other such states.

Memory.—There is abundant evidence that ants retain memories of past experiences. Thus, for instance, if they locate a distant food supply, they will return time and time again to the treasure, attracted by their memories of what is to be obtained at the distant spot. When slave-making ants, out on a raid, are unable to bring back all the pupæ of a plundered nest in a single trip, they return the same or the next day to gather the remainder of the booty. But after they have taken all of the pupæ, they never return again, their memories of the exhaustion of the treasure controlling them. Similarly, hundreds of other examples might be given to show that ants retain memories of their past experiences.

FIG. 443.—WATCHING ANTS

But it is not evident that ants show much higher intelligence than that.

You will find great entertainment in the careful watching of ants. So set to observing for yourself what things these remarkable insects are capable of doing.

SUMMARY

1. The ant colony includes a few queens, many workers, and some drones. The queens and drones may be winged, the workers are always wingless. Clusters of tiny, pearl-like eggs, many helpless larvæ, and naked or cocoon-covered pupæ will also be found in the nest. Most of the activities of the colony are concerned with the care of the young.

2. Ant nests may be tunnels made in the ground, often under thin stones. Some ants build mounds of dirt and plant debris which, decaying, serves as an incubator for the young. Many ants nest in decaying wood, or in hollow stems; some use paper or silk in building their nests. The nest is kept carefully cleaned, the entrances are guarded in the day and closed at night.

3. No animal can become social unless it has learned to use plant foods. Most ants use some vegetable food. The harvester ants of Texas and the Southwest depend largely on grains which they carefully harvest. The leaf-cutter ants wet down masses of cut leaves until they decay; then they grow fungi on them, and feed on the fungi. The honey ants gather sweet secretions of plants (chiefly from oak galls) and store the honey in the swollen abdomens of certain of their workers.

4. The driver ants of the tropics are nearly blind, depending on their sense of smell to locate animals which they devour with great ferocity. Many ants are slave-makers, stealing pupæ of other ants, eating some of the pupæ, but caring for the others until they mature and become workers in the colony. The Amazon ants have sickle-shaped jaws admirable for fighting but useless for feeding, so they depend upon their slaves for their food.

5. Other ants are thieves, hired soldiers, shampoo experts, traitors, and murderers.

6. Many ants keep plant lice or scale insects as cattle, caring for the guests, and feeding on their sweet or waxy secretions.

7. Termites are among the most important pests of the tropics. There they destroy all man-made materials built of wood. They live in social colonies remarkably similar to those of the ants, except that they have worker males as well as females.

8. Ant and termite colonies are kept together by the common food supply. They are especially attracted by the sweet secretions that are found on the bodies of the larvæ. Much of their behavior is simple reflex or tropism, or chains of such behavior. They have especially well-developed organs of taste and smell, so much of their behavior represents responses to chemical stimuli.

9. Ants show considerable ability in remembering their experiences.

10. The observation of these remarkable social insects may provide endless entertainment for the person who will take time to look at them.

DEFINE

Castes (among ants)
Soldiers (among ants)
Termite

PROBLEMS

1. What is the most interesting thing that you, personally, have observed ants doing?

2. Ants are among the most successful animals in existence. There are many things favoring their success. What are some of them?

3. How many different kinds of ant nests have you ever observed? Describe their locations, materials, form, size, etc.

4. What three or four things about ant behavior will you remember as especially interesting?

5. Take any four of the stories told in this chapter. Can you classify these cases of ant behavior as reflex, tropism, instinct, or memory, or a combination of these?

6. What are the chief differences between the way a honeybee and an ant colony is organized?

7. How many of the things done in human society are done, in a way, by ant colonies? List them.

8. Is it worth *your* while to find an ant colony and observe it? Why?

9. Have you ever observed termites? Report what you have observed.

10. How many different kinds of ants do you suppose there are in your part of your state? How many kinds have you ever seen?

11. List ways in which ants are economically beneficial and harmful.

12. List ways in which termites are economically beneficial and harmful.

13. On the basis of what you now know about the insects, tell how you would control ants in your pantry.

14. Discuss methods of control of termites. You may be able to find special literature, or you may reason out some things from what you know of termites.

15. What are some of the important differences between human society and an ant or termite society?

CHAPTER XLIII

PARASITISM

It is difficult for an animal to eat its food without so killing and destroying the supply that famine follows the days of plenty. How can one eat a goose and still get the daily supply of eggs? How can one eat the beef of a cow and still milk her twice a day?

But there are numerous organisms that have found satisfactory answers to these questions. The flea and the louse, the tick and the maggot, and the whole assembly of parasites, testify that the way is to live with the food supply, to live in and to feed on the food supply, but never to kill it until its usefulness is over.

The Parasite's Problems

Now, the problems to be solved in undertaking parasitism are these:

1. The food material, whether it be plant or animal, must be fresh and alive.

2. Feeding must be done in such a way as not to prove fatal to the food supply, or else starvation may stalk in the future.

3. In order that food may be available at any and every moment, the parasite must learn how to live on or in its food supply (politely called its *host,* although the visitor is more willing than the visited).

4. A particular species of host must be chosen to bear the whole attack, for few parasites have the equipment to lay hold of any and every thing that comes along.

5. The parasite's mouth, claws, and digestive apparatus, and the shape of its body must become adapted for the life with the chosen host.

6. Finally, it will be necessary for the parasite to become (instinctively) familiar with the ways of its host, so it may be able to get along with the host in every one of its life-long activities.

The parasite, you see, lives a double life, its own and that of its host; and its behavior must be ordered to accomplish, without too much chance of failure, the successive steps by which it may reach the host, lay hold of it, feed on it, and live with it. Further, its offspring must find similarly suitable hosts.

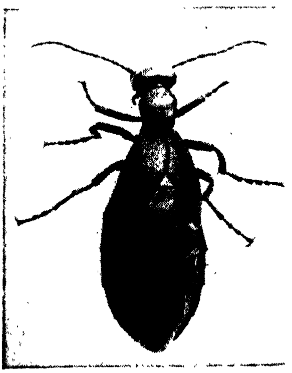
It is evident that the mechanical types of behavior, particularly instinct, are the ones most likely to serve the purposes of the parasite.

Typical Parasite Behavior

Consider some instances, and see what machines of instinct parasites may be.

Liver Fluke.—Consider the liver fluke, a flatworm which we have already described. What a precise thing it is that leads the newly hatched worm to wander about until it finds a water snail into which it may crawl! There is the proper food for its young self. A blind but impelling force leads the worm, after a while, to leave its snail host, and to crawl out onto the grass at the edge of the pond. The worm is not conscious of the fact that feeding sheep are likely to come along and pick it up, but its instinctive equipment is a sufficient guide for it to follow. We do not know how many parasites go astray and get on the wrong hosts, attaching to those on which they cannot survive; but that the worms are successful as often as they are testifies that there is some efficiency to the workings of instinct. After the fluke has been taken into the digestive tract of the sheep, it, again mechanically, seeks the liver of its host, and there it finds the food proper for its maturing.

Oil Beetles.—Consider the case of certain of our oil beetles, the blue or bluish-black adults of which look as if they were wearing hoop skirts! The eggs of these insects are laid in the ground, a single female sometimes laying as many as three or four thousand eggs. These give rise to active little larvæ that run about and climb the stems of flowering plants, where they wait for a chance to attach themselves to some hairy object. When this proves to be an insect which is not a fit host, the larval beetles die. Most of them never succeed in getting further in their parasitic careers.



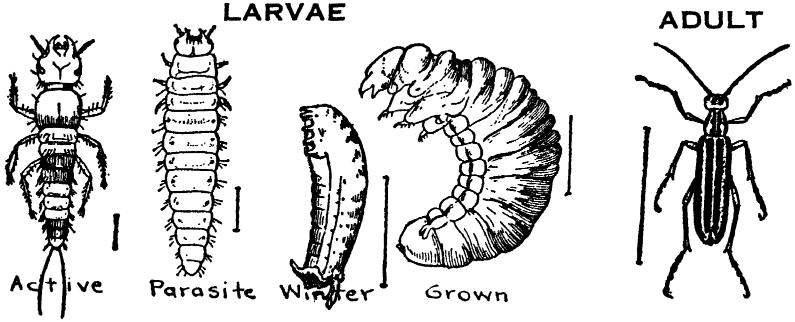
From Riley and Johannsen's Medical Entomology

FIG. 444.—AN OIL BEETLE

But if the host is one of the long-tongued, wild bees that commonly visit flowers, the beetle is well started on its journey. Observations on the European relatives of the oil beetle indicate that the bee usually laid hold of there is a male, for those are the first bees abroad in the springtime; but later the larva takes an opportunity to transfer to a female of the same species; and riding on her, the thief gets into the bee's nest and to the very honey chambers of the nest. This is the desired goal.

As the female bee lays an egg in the honey cell, the beetle larva slips off onto it, and using it as a raft, floats on top of the liquid food. The parent bee closes the cell, and the parasite is left to feed upon the egg. In time the egg becomes so far eaten that it cannot support the parasite, and then the beetle larva molts and becomes a very differently shaped animal, a sort of raft itself, which can float directly on the honey while eating of the sweet stuff. A couple of months after entering the bee's nest, and after both egg and honey supply have been exhausted, the beetle completes its development and crawls out of the bee's nest to lay its eggs where the next generation can begin life.

What a series of events the oil beetle larva must go through in a certain, strict order: the hatching and active exploration of the neighborhood, the grasping of a hairy passerby, the shift from the male to the female bee, the shift from the bee to the egg, and finally the change of its food and of its attachment from the egg to the honey! It is not surprising that the beetle has to lay a thousand times as many eggs as would be necessary to maintain the species under normal conditions. The wonder is rather that tiny insects that have never had any practice at doing these things, and that have never seen any other beetle do them, should, instinctively, be able to succeed as often as they do.

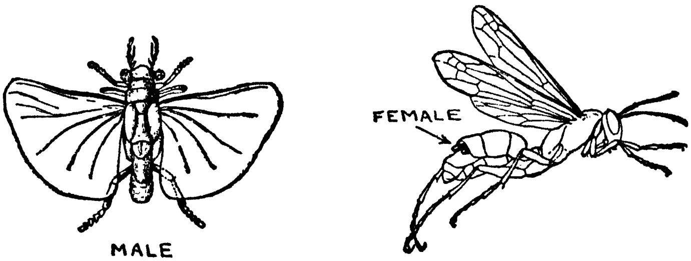


From Lutz' Field Book of Insects, Putnam Publ.

FIG. 445.—LIFE HISTORY OF ANOTHER OIL BEETLE

Stylops.—Other peculiar, very tiny, beetle-like insects called *Stylops* parasitize wasps and bees even more directly. The female Stylops is a very simple, degenerate, and grub-like insect; and she always lives within the abdomen of adult wasps or bees, her head just showing outside. She feeds by absorbing nourishment from her host directly through her own thin skin. She produces her eggs without leaving her host, and the hatching Stylops larvæ crawl out and all over the body of the wasp, remaining there until they are carried to the wasp's nest. Or they may drop off of the first wasp into a flower or onto something else, and wait for a chance to catch hold of other passersby on which they may ride into another nest.

There they hunt until they find larval wasps into which they burrow. Inside their hosts, parasitic life soon causes their legs to disappear, and their eyes to go, and, if they are females, the insects become as grub-like as their mother. If they are males, they undergo a more normal development, and in time they crawl out of their hosts and fly away as tiny adults, less than a quarter of an inch in length. These males mate with the females as the latter lie at the surfaces of their hosts. All of this time the hosts have been the living victims, the living food factories for the parasites, and they are only occasionally killed by the Stylops. Rarely do the parasites penetrate vital organs of the hosts. Instinctively the things avoid killing their sources of food.



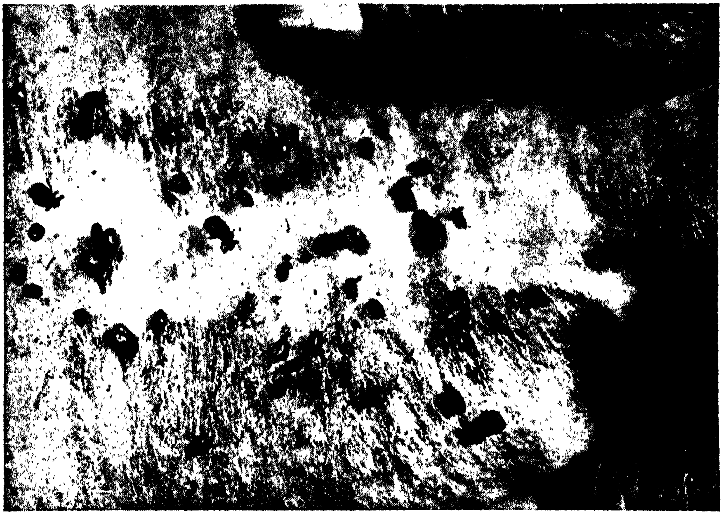
From Lutz' Field Book of Insects, Putnam Publ.

FIG. 446.—STYLOPS, MALE AND FEMALE
The female protruding from the abdomen of a wasp.

Host Relations of Parasites

All of the evidence indicates that parasitism originated in the animal world as a special form of predatism. The predator pounces upon its prey, kills it, and then eats it. The parasite merely eats before killing. The predaceous cat, playing with its live mouse, gives some suggestion of how a parasitic habit might develop. The tiny protozoon or worm or wasp that is much smaller than its victim could not well escape becoming parasitic, at least until it had time to eat enough of its host to kill it, or until it could deal a vital stroke to the host. Clearly, parasitic behavior is modified predatory behavior.

The most primitive parasitic species now in existence are those that feed more or less indiscriminately upon anything that comes along. The more highly evolved parasites are all very particular in choosing their hosts. This is true for the parasitic wasps, for the biting lice of birds and of mammals, for the sucking lice of the human and other mammals, and for many other groups of parasites.



Courtesy U. S. Bur. Animal Industry

FIG. 447.—"TICKS" ON THE NECK OF A SHEEP
This species is a peculiar type of parasitic fly.

Indeed, each species among the specialized parasites is often confined to a single species of host. So strictly true is this that it is sometimes easier to identify the host from the parasites it bears than it is from the characters of the host itself.

Among the instances of very specialized choices of host, there are two of the species of lice which occur on the human.

The head louse occurs on the hairs, mostly the hairs of the head of its victim, while the body louse lives in the clothing worn by its host, and leaves that clothing only temporarily while feeding. There are few differences in the appearances of the head louse and the body louse, and there can be no doubt that the two belonged to a single species, once upon a time. Even though their structures have not evolved very much, the two parasites are now easily distinguished by their behavior.

Incidentally, we have some measure of how recently this louse behavior has evolved, for there is reason to believe that the head louse was the original type, and the body louse could not have adopted its ways before the human animal began wearing clothing. This illustrates how closely the evolution of a parasite's behavior depends upon the history of its host.

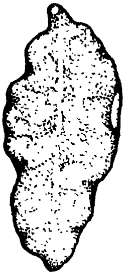


FIG. 448.—ADULT LIVER FLUKE

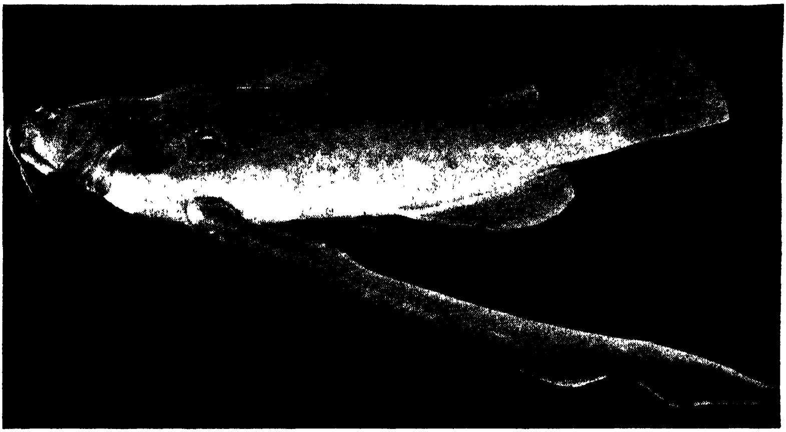
A parasitic flatworm, lacking sense organs and special structures; with an indefinite, much branched digestive system.

Parasitism and Degeneration

Degeneration is evolution from a more complex to a simpler form. If ever plants or animals have degenerated, parasites are one of the results. They are notoriously simple in structure, lacking whole parts which normal organisms have, and having few complicated structures of any sort. They are often eyeless, they often lack antennæ and other special sense organs, they are usually legless, they are often flattened and worm-like, and their digestive systems are usually very simple or entirely lacking. This is more or less true of all animal parasites.

An abundance of good evidence indicates that the simple-bodied parasites have come from forms that were very well developed structurally. The simplicity is the result of great specialization and is not the simplicity that primitive, ancestral organisms show.

The parasite is always likely to become degenerate. Especially if it lives within the body of its host, it has little need for special means of defense, or for sense organs, or for legs for travelling. Many animals that are born with normal legs lose them as soon as they take on parasitic ways and become established with their hosts. They often absorb food directly through their skins, and their digestive tracts become much simplified in structure.



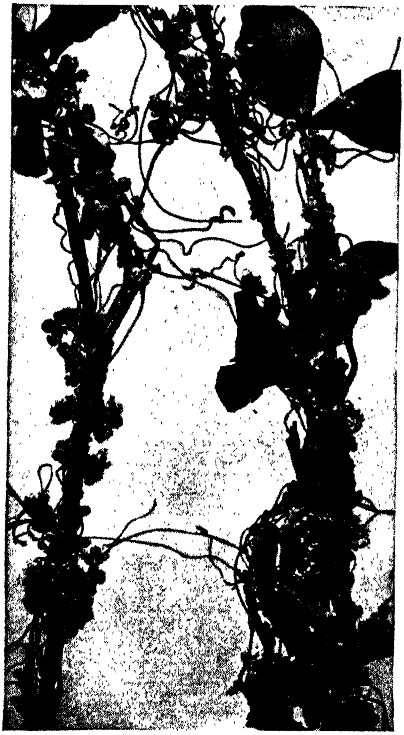
Courtesy Amer. Mus. Nat. Hist.

FIG. 449.—THE LAMPREY, A PARASITIC VERTEBRATE

The parasite, a relative of the true fishes, is attached to a catfish. The circular mouth, which lacks jaws, allows the parasite to attach to its host. With its rasping teeth and sucking mouth the lamprey draws blood from the catfish. Note the absence of limbs in the parasite.

Many of the parasitic plants are characterized by their lack of green leaves. They do not need them, for they do not manufacture their own foods. The dodder, a plant that commonly parasitizes clovers, wheat, and other things, starts in life with normal roots, but it loses them after it has become attached to its host.

Disadvantages of Parasitism.—The structural degeneracy of a parasite is often its undoing. It is all very well to have everything delivered directly to one's own mouth, and to be carried about and protected by a host. That is, it is all very well as long as things go well with the host. But the parasite must reap not only the ill-fortune that may come to one individual, itself, but in addition all of that which is coming to its host. When difficulties reach the host, the degenerate parasite finds itself without means of defense or of seeking a new food supply. When a bird is killed, all of the biting lice which have up to now been thriving on the bird are left helpless and hopeless, doomed to a speedy death from starvation. The poor little rich boy who has always had servants do things for him would find himself in an awkward circumstance if his servants should expire and there were no means in the wide world of ever getting other ones.



Courtesy U. S. Bur. Plant Industry

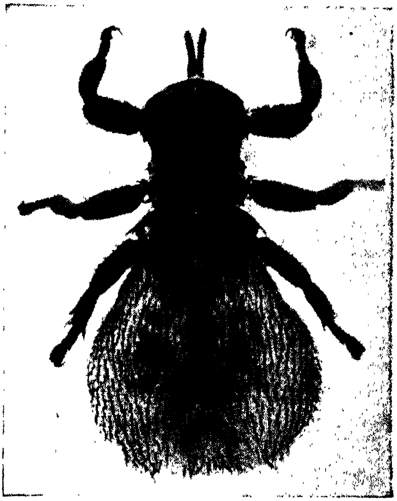
FIG. 450.—DODDER ON CLOVER

A parasitic plant that loses its roots after attaching to its host.

The disadvantageous results of parasitism are further shown up by a comparison of the *permanent* and the *temporary* parasites among the insects. The permanent parasites are parasitic throughout their lives, as bird lice and human lice may be. The temporary parasites are parasitic only in their larval stages, and are free-living, active and independently feeding insects after they become adults. The solitary and parasitic wasps are all temporary parasites. They do not suffer many of the ill-effects of parasitism because they finally become able to fly about, and then they can escape enemies and scatter their offspring far and wide.

But parasitic animals, whether temporary or permanent parasites, are not degenerate in their instinctive behavior which is, as we have seen, often extremely complicated.

Since most of our domesticated animals are infested with insect parasites, you may collect and acquire some first-hand acquaintance with them. If you come across freshly-killed, wild birds or mammals, you should certainly look for parasites on them. Scientists know so little about these peculiar forms that your collections should prove of interest to the specialists, and any observations you can make on the relations of the parasites and their hosts may add to our knowledge of this phase of biology. You, I am certain, will be repaid for the attention you may give this part of the living world about you.



Courtesy U. S. Bur. Animal Industry

FIG. 451.—THE SHEEP "TICK," A DEGENERATE, PARASITIC FLY

Wingless and peculiarly shaped for its parasitic life.

In the next chapter we shall describe the behavior of the most remarkable of all parasitic animals, the solitary wasps and the solitary bees.

SUMMARY

1. Parasites are plants or animals that live with their food supply and feed on it without killing it (at least without killing it immediately). The most successful parasites are specialized feeders, adapted for living on a particular species of host into whose life the life of the parasite must fit.

2. Three cases of typically parasitic behavior are discussed. At each stage of its life, each of these parasites changes its form and behaves in a way best calculated to serve it under those particular circumstances.

3. The liver fluke moves from the ground, to a water snail, to grass on the edge of the pond, to the stomachs of sheep, to the liver of sheep.

4. The oil beetle larva moves from the ground to the top of a flower, to a male bee, to a female bee, to the bee's egg in the nest, to the honey in the nest, to a free life as an adult.

5. The Stylops female lives in the abdomen of a wasp or bee, the larvæ riding on the insect until they meet with other hosts. The Stylops male is more normal.

6. Parasitism is a special form of predatism. It is delayed predatism.

7. Primitive parasites are general feeders; specialized parasites are usually confined to a single species of host. Many parasites, like the human lice, are confined to particular parts of a particular host.

8. Parasites are almost always degenerate—meaning that they are simpler in structure than the ancestors from which they evolved. This is true of both plant and animal parasites. Animal parasites, however, often exhibit more complicated behavior than any free-living forms.

9. Parasites reap all the misfortunes that befall their hosts as well as those that come to them directly. Because they are so specialized in structures, parasites cannot live if their hosts are taken away.

10. More successful than the permanent parasites are the temporary parasites, for the latter are free-living in their adult stages and then can move about and accomplish the distribution of their offspring.

DEFINE

Parasitism
Degeneration
Host

Permanent parasite
Temporary parasite

PROBLEMS

1. How many kinds of parasitic animals can you name? Prepare a list.
2. Name some parasitic plants.
3. Why have we not given more consideration to parasitic plants in this discussion of parasitic behavior?
4. Is degeneration evolution backward or forward? Are you sure?
5. How might the experiences of animal parasites be applied to man and human society?
6. What are the disadvantages of parasitism for a parasitic plant?
7. It has been said that the human animal is parasitic throughout infancy and childhood. Is this a fair statement? Be prepared to debate this subject.

CHAPTER XLIV

SOLITARY WASPS AND BEES

Fastened onto the rafters of the old shed, there is a nest of clustered mud tubes. Each tube has the shape and diameter of a finger, and the cluster bears somewhat the appearance of a tier of organ pipes flattened against their support. There is another cluster in the shed that has a two-story arrangement of the pipes, but single stories seem preferred.

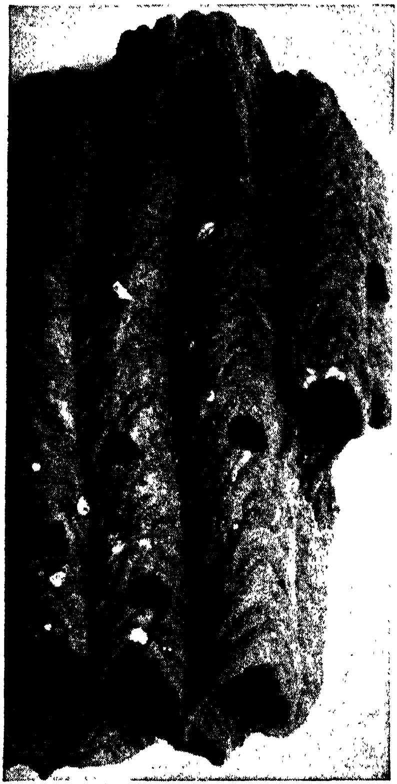
The Mud-Daubers

These are the nests of one of the mud-dauber wasps, those steel-blue, or black-and-yellow, slender-waisted creatures that may be seen about the mud-puddles, busily kneading the clay into the right consistency. There are several species of mud-daubers, each with its own distinctive dress and form of nest. If we had followed the particular species that makes the organ pipes, early in the summer, we might have seen some such behavior as the following.

Building the Nests.—The mud is carried home in the insect's jaws. Already a part of one of the tubes is completed, dried, and hardened, and the new load of materials, worked with the wasp's legs and jaws, will suffice to add another layer a quarter of the distance around the tube. It is a solid day's work to build one of the pipes, even if it is not very far distant from the puddle that supplies the mud.

The wasp makes no attempt to cover the imperfections of the outside of the structure, but lines the inner walls with a smooth layer of mud that nicely protects the inhabitants.

And who are the inhabitants? The wasp that did the building? With extra bedrooms for her numerous offspring?



Courtesy Phil Rau

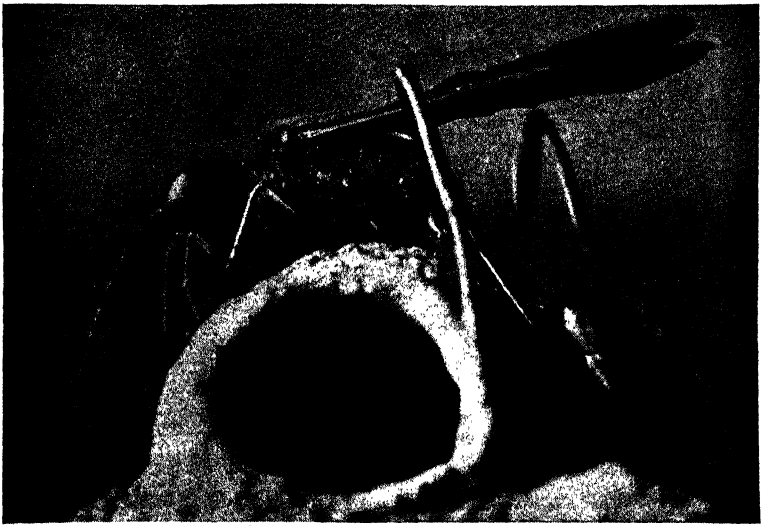
FIG. 452.—MUD-DAUBER NESTS

Let us see! Break into the establishment, and find a surprise! Each room is crammed full of spiders! A wasp building habitations for spiders? What can it mean? Many a curious boy knows this mystery. But curiosity alone won't solve it. At least another virtue, patience, the ability to watch the tiny creatures for hours and days, must be claimed if one is to have a first-hand acquaintance with the ways of this wasp world.

Capturing Spiders.—Had we followed Mrs. Wasp after she finished her building, we should have found her hunting spiders. It is hard to understand where she gets them all, for a hundred of them are necessary for her one household. One nesting made by a related species of wasp in the cut straws of a straw stack was estimated to contain something like six thousand spider victims.

Into the highways and byways of spiderdom, over grassy paths, into the chinks in the old stone wall, even into the webs of the spiders themselves, these wasps go to secure guests for the feast. Only the guests are not so much invited as compelled in their attendance.

Playing back and forth before the spider, who herself is no mean warrior and huntress, the wasp seizes a favorable opportunity and pounces upon her prey, thrusting at the same instant with her poisoned lance, which is the sting in the tip of her abdomen. One stroke, and the spider is—paralyzed! In the leisure of another moment, the wasp may sting again and again, but the victim is not killed. Its attendance at the feast is to be as a living sacrifice, the feast itself, nicely prevented by the paralysis from engaging in unmannerly conduct or an attempted escape, and as nicely prevented from unwholesome decay should the feasting be protracted.



Courtesy P. G. Howes and Nature Magazine

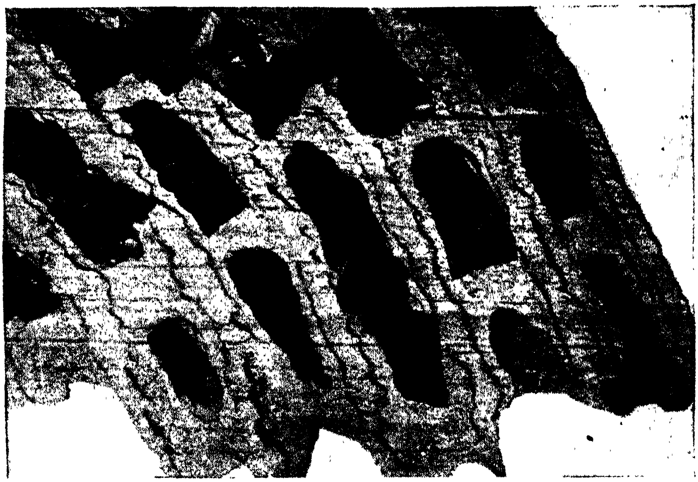
FIG. 453.—A MUD-DAUBER SHAPING ITS NEST

But who are the true guests?

Mother mud-dauber stocks each chamber of her pantry "one to a dozen spiders," tops it with a layer of mud that partitions the long finger, and so continues, making three or four cells in each finger, and eight or ten fingers in the colony.

All of this provisioning is done through the lower ends of the chambers, which remain open until a whole finger is filled. It is a wonder that the spiders do not fall out of these upside-down lockers.

Father wasp is close about while his spouse works. The genus to which this mud-dauber belongs includes the only wasps with males that take any special interest in the nesting. While the female hunts spiders the male climbs into the mud chamber and hangs on guard, even chasing away would-be intruders, parasites, and other marauding insects. When Mrs. Wasp returns, he gallantly moves out to let her enter, and then, climbing onto her back, goes riding into the chamber, and he may even help in storing the booty.



Courtesy Phil Rau

FIG. 454.—"AND FIND A SURPRISE"
Mud-dauber nests filled with spiders.

The Baby Wasps.—But neither of these wasps attends the banquet. The whole set of cells filled, their ends finally capped with mud, the parents leave the spot and from then on find no interest in it. What prodigious labors at preparing a feast which they will never share! There is no room to doubt that some impelling instinct is the mechanical stimulus to this behavior.

Let us open one of these halls and try to discover who is banqueting. If it is a newly stored cell, it will be hard to find anything but spiders. But some searching will reveal an egg, a tiny, white melon-shaped egg attached to the abdomen of one of the spiders, and here is the clue to the whole performance. This is the egg that the mother wasp has laid. These spiders are the provisions that she brought for a baby that she will never see. The paralyzing of the spiders prevented damage to the egg and now to the delicate wasp larva that is hatching from it, while offering some guarantee of fresh food through the feasting days of the infant.

The youngster first bites into the tender abdomens of its dinner, not unlike some other organisms who first eat the icing off of their cake. Living as a parasite on the stored spiders, it finishes what food is provided and pupates, in time transforming into another thread-waisted, broad-winged insect who will chew her way out of the mud chamber and go forth to build and provision for yet other generations.

One other point to notice: The exit holes of these mud-daubers are all on the side of the tube which is away from the supporting beam. If we examine the interior walls of the tubes, we shall find no indication that the insects mistakenly attempted to emerge in the wrong direction, beamside. How do the wasps, in the dark of their cells, shut off by thick walls from the light and the open which they have as yet never known, discover on which side to make their exit?

This is but a poor, second-hand record of a common-enough creature. It gives little hint of the delights your own observations may furnish you, and it leaves unanswered many questions which are still to be put to the wasps.

Though the mud-daubers are possibly the best-known of the solitary wasps, they represent but a half dozen of the ten thousand or more species there are among the families of solitary wasps and bees. Each of these has its own peculiarities of behavior. Each builds and provisions in its own interesting fashion. But beyond the mud-dauber, we shall not be able to give a detailed account of any species. For that you should read in the delightful books[1] that have been written about these insects. Here we shall have to be content with a summary of some of the things that these wasps and bees are known to do.

From Bicknell's "Fabre." Courtesy Century Co.

FIG. 455.—HENRI FABRE, THE FRENCH ENTOMOLOGIST
Student of wasp and bee behavior.

The Food Materials

These insects are called solitary because they do not live in social communities as do the ants and bees and the wasps that we have already considered. Each solitary mother works independently, building and provisioning for her young, but quitting the region and dying without spending a day or an hour with those offspring.

All of the solitary wasps provision their nests with animal food, and with few exceptions they paralyze it before they place it in their cells. The young wasps become parasites on this paralyzed food. Most of the solitary bees provide for their larvæ with a pollen and honey paste that is packed into the nurseries as the eggs are laid.

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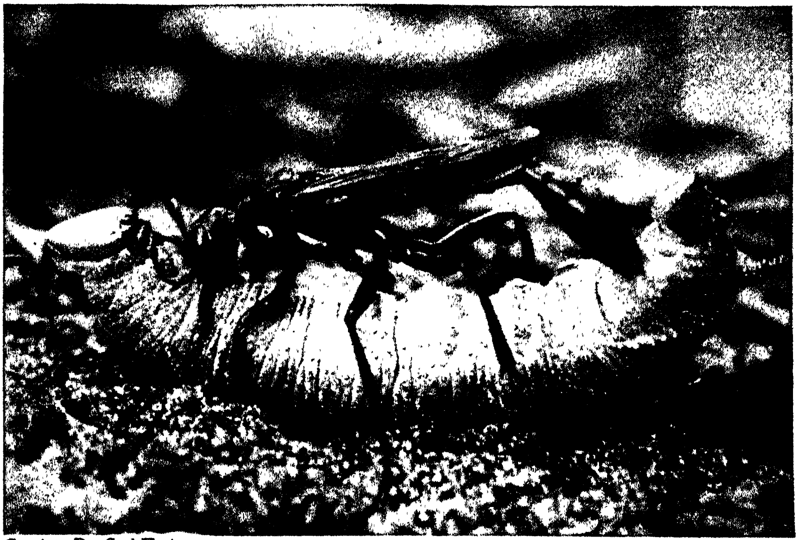
[1] Peckham, G. W. and E. G. Wasps, Social and Solitary. Houghton Mifflin Co. Boston: 1905.

Rau, Phil and Nellie. Wasp Studies Afield. Princeton University Press. Princeton, New Jersey: 1918.

Fabre, J. H. Many volumes, the English translations published by Dodd, Mead & Co., New York City. *See particularly* The Mason Wasps, The Mason Bees, The Hunting Wasps, More Hunting Wasps, and Bramble Bees and Others.

For further references, see the list of books given at the end of this unit on Behavior.

Particular Kinds of Food.—Many species of the solitary wasps choose but a single kind of prey. It may be a spider of one kind, or a spider of another kind, or a grasshopper, or a katydid, or a cricket. Flies, beetles, caterpillars, plant lice, grubs, and still other insects sometimes serve as victims.



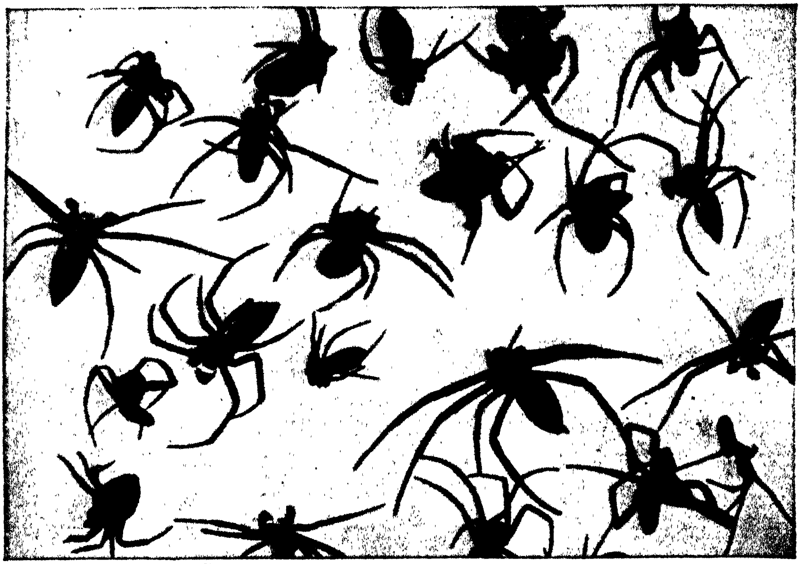
Courtesy Dr. Carl Hartman

FIG. 456.—PARALYZING A CATERPILLAR

The victim is deftly turned on its back; then the wasp inserts her sting while holding the prey with her legs and jaws.

Instinctively, the wasp knows the habits of her particular game. If spiders are the fare of her species, she knows how to avoid their poisoned fangs and their silken snares. She can pursue them into cracks and holes with impunity. It is even claimed that at times she jiggles their webs in order to bring them into the open, and the dangerous European tarantula is enticed out of her hole into the tall grass where she is more readily outwitted by the wasps.

Species that gather the larvæ of beetles, such as white grubs that live at some depth in the ground, show an ability to locate their prey even under unbroken ground, and they dig for the grubs with considerable accuracy. All of this suggests that the insects possess sense organs that are far more delicate than those of the human.



Courtesy W. M. Savin, N. Y.

FIG. 457.—PARALYZED SPIDERS FROM ONE MUD-DAUBER'S NEST

For soft-bodied food material the wasps dig nests in damp soil. There the food will not dry out and die, as it would if placed in the dry nests which most of the insects build.

Amount of Food.—The amount of food taken by any one wasp varies with the species and the individual. One mud-dauber may put only a single spider in each cell, while another uses as many as fifteen. The same wasp may stock two successive cells with different amounts of food, unnecessarily indulging one of her babies, starving the next. Usually the last cells built are the ones most poorly supplied, indicating that even instinct becomes wearied by hard labor and fails in the end. With many wasps a single large caterpillar is a sufficient supply for each cell. If smaller prey is used it must be more abundant, and a score of tiny caterpillars may be needed. One wasp used seventy-nine house flies in provisioning a nest that had only a single cell in it.

Solitary Bees.—The solitary bees gather the pollen of flowers for their young. In the center of the powdery masses they place goodly drops of honey and deposit the eggs in these. The larvæ, born as it were inside their porridge bowls, drink honey until that food is exhausted, and then they are probably better able to live on the highly protein diet which the remaining food, pollen, affords.

Nests and Nest Building

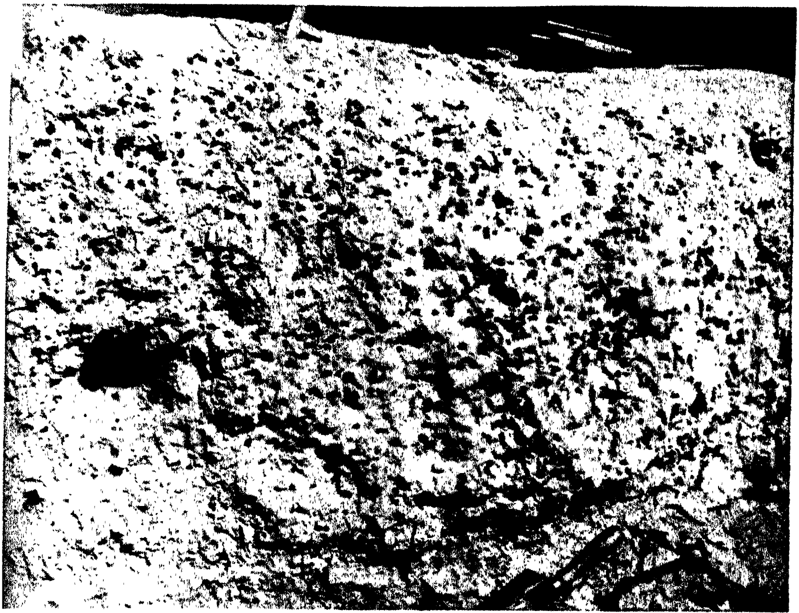
Considering the whole group of solitaries, it may be said that they nest everywhere. But here again there are great differences in the ways of the various species.

Some build in any kind of location. These are usually the lazy ones (or the clever ones?) which are quick to utilize any advantage that is offered by a ready-made crack in the wall, an abandoned spider hole in the ground, the hollow of a spool that once bore man-made thread, or the empty vaults of some snail shell.

In any event, each wasp builds close to the spot where she was born, possibly not more than a few yards or even inches from the parental home. For this reason, the find of a single nest usually presages many others in the immediate neighborhood, unless, of course, the insects have done as the mud-daubers that were found building on the sides of freight cars, and sending their progeny country-wide!

Most of the solitary wasps and bees build in very particular places. Sometimes it is a mud nest above ground. This is made out of either ordinary dirt and water that is likely to go to pieces in the first rain storm, or a mortar made waterproof with what is probably saliva.

The irregularly formed nests of some of the mud-daubers, and even the more precise pipes of others, are surpassed by the astonishingly regular, jug-shaped nests of the potter wasps, who turn their clay into as thin-walled, as regularly formed, and as finely tapered jugs as the human potter that works with a potter's wheel. One tropic mud-wasp that has to use the bright red clay of her region makes her nest less conspicuous by covering it with the cast wings of ants and with other debris.

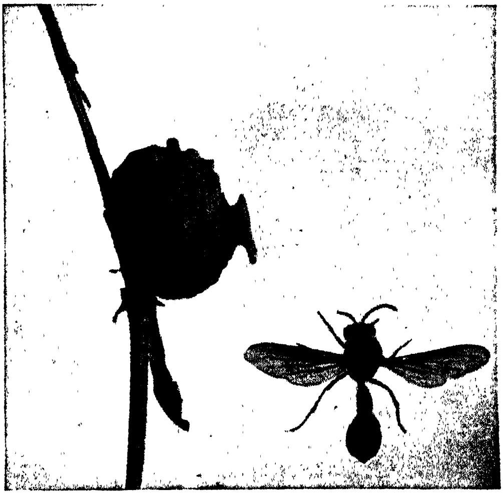


Courtesy Phil Rau and Princeton Univ. Press

FIG. 458.—NESTING HOLES OF A MINING BEE IN A BANK OF EARTH

Often the nests, particularly of the solitary bees, are located in hollow straws or weeds, or in excavated blackberry briars or other woody stems. Some species work in logs, chiselling wood like carpenters, and building partitions of sawdust mixed with saliva. Many dig burrows in the ground, and innocent-looking holes, no larger around than a lead pencil, are always worth close and patient observation, for there you may have the open door to a wasp drama that is being enacted underground.

Nest-Building.—Mrs. Solitary is just digging her nest. With legs and jaws she is breaking into the hard soil. Here she comes now, previously announced by the shower of earth which she kicks a-flying in backing out of the hole. All of the dislodged material will be scattered so thoroughly that no sign of active operations will remain to attract an intruder.

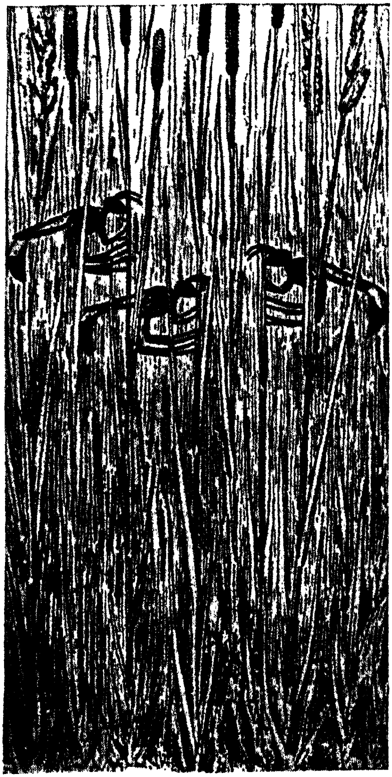


Courtesy Conn. Agric. Exp. Sta.

FIG. 459.—A MUD JUG AND THE POTTER

The hole is dug down almost vertically for a short distance, and then at an angle more parallel with the surface of the field. At the end of the tunnel a single enlarged chamber is prepared to receive the eggs. Some species place several such chambers at different levels as side pockets from the central shaft. Sometimes nests are found within an inch or two of the surface. They have been located as far as twenty-nine inches from the entrances.

Withal, it is a heavy lot of work that is done. Perhaps a thousand times the wasp-weight in dirt is removed. It is about as though a man had seventy or eighty tons to dig. The industry of the mother is often continuous from the time the hole is started until it is finished. Some species have even been observed to work straight on through the night. One individual worked for forty-two consecutive hours without stopping!

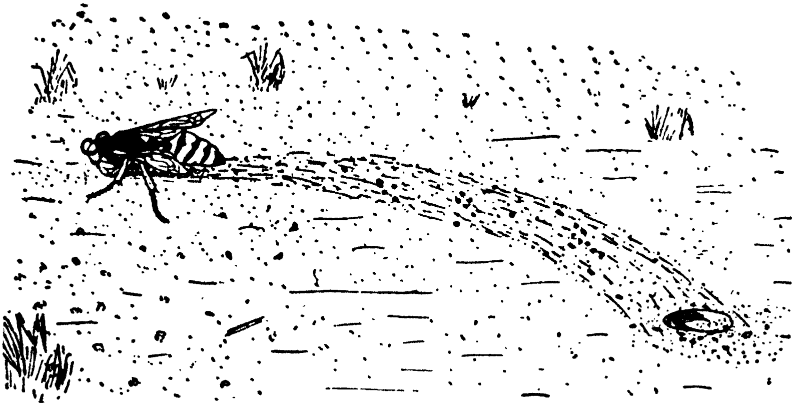


After Peckham. Courtesy Houghton Mifflin Co.

FIG. 460.—SOLITARY WASPS ASLEEP IN THE GRASS

Most of the wasps, however, finish their tunnels by sunset, and then they rest. Through the night they sleep as soundly as many of the higher animals. Some species seek the cavities of old stone walls and lie on their backs in positions ridiculously suggestive of the sleeping human. Many of the wasps and bees cluster by the scores and hundreds for the night, making a beam in some old barn, or the broad surface of some flower head or leaf, or some other natural covering, the roof for the public dormitory. You may readily observe these remarkable doings if you will arm yourself with a flashlight and venture out-of-doors at dusk or later some summer evening. Still others of the solitary mothers may crawl into the holes they have been digging in the day; and drawing in or kicking up enough dirt to seal the entrances, they go to sleep there for the night.

Provisioning the Nest.—Bursting forth in the morning with a volcanic eruption of earth, the insects now set about the task of finding provisions. It is interesting that all but a few of the wasps delay this search for food until after the larder is built. To gather food first would be bad practice, for then some of the parasitic flies and wasps that are continually hanging about would have a chance to place their own eggs where they might later find the opportunity to become parasitic on the solitary babies themselves. One of the wasps that does gather its prey before digging the nest, hangs it up in the branches of some plant, where it is at any rate safer from ants and other ground-inhabiting marauders. Another such wasp stores the prey in some such crevice as may be furnished by a stone wall, while it does its digging.



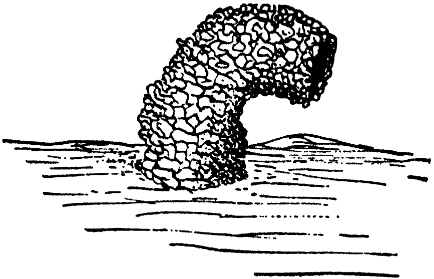
Courtesy Phil Rau and Princeton Univ. Press

FIG. 461.—DIRT IS BRUSHED INTO THE NESTS WITH SURPRISINGLY ACCURATE AIM

If several paralyzed guests are to grace the feast, the mother must deposit them at intervals broken by her hunting expeditions. The top of the nest is usually plugged with earth whenever the mother is away, and in that way undesirable visitors are prevented from gaining entrance.

The wasp's egg is usually laid as the last provisions are interred.

Closing the Nest.—The nest being completely stocked, the mother sets to work to refilling all but the innermost chamber of the hole. That is, she sets to work to do what she undid, as it were, only a short time before. Her instincts now lead in a direction just opposite to where they led before. The completed nest had become the stimulus to the next link in this behavior chain, and consequently the wings and legs of the wasp are set to sweeping the dirt into the hole. The material is worked in with the insect's legs and packed down and pounded by the tip of her abdomen, which she joggles around in the hole as a living pestle. Sometimes part of this earth is made into a plasterer's clay by water which the insect brings in her mouth and disgorges a bit at a time as she works the soil.



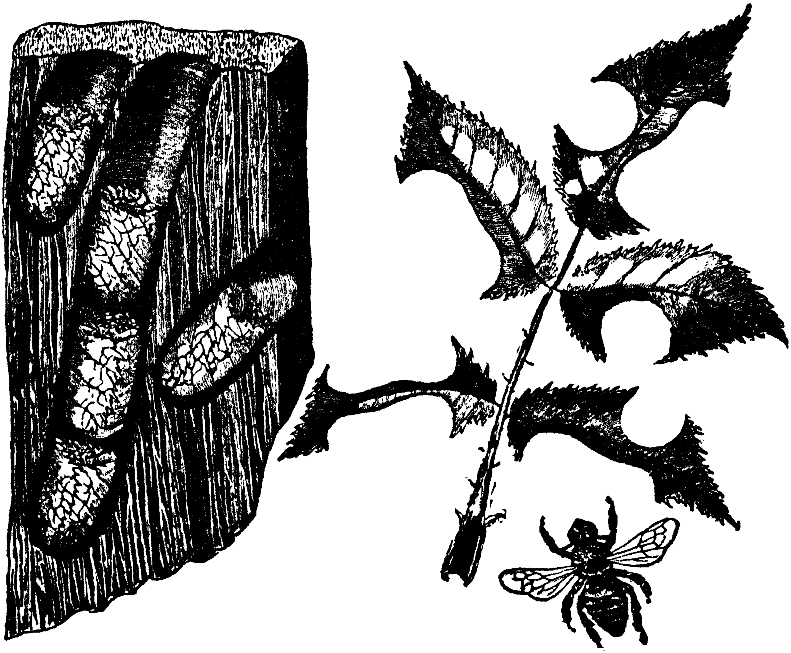
Courtesy Phil Rau and Princeton Univ. Press

FIG. 462.—THE TURRET OF A SOLITARY WASP

Twice actual size.

One species of solitary wasp that lives on the salt marshes near San Francisco Bay removes a hardened, salt-incrusted, circular bit from the ground before she does any digging, and places the cake carefully to one side, though she scatters the rest of the dirt high and wide as she digs. In filling her hole she uses materials that she gathers from anywhere, but at the last she places her treasured bit of salty crust on the spot from which it was first removed, and when she goes away she leaves no sign that the place was ever disturbed.

Another species carefully piles her excavated earth about the mouth of the pit, building a turret that mounts an inch or so above the level of the ground. The earth that is dug out toward the end of the operation is, however, scattered widely and completely discarded. When the refilling commences, the wasp uses only the materials which went into the turret, and, incredible as it seems, she comes out exactly even, with the hole filled to the level! The earth that she discarded was out of the larval chamber that needed no refilling, and every bit of the earth that was taken from the tunnel itself went into the turret, and then back into the tunnel. How did the wasp ever learn to measure with such a nicety? How did it ever learn that such precision was better than more slipshod methods? Such are some of the things that we wonder about in considering this instinctive behavior.



Courtesy Prof. J. H. Comstock, Cornell Univ.

FIG. 463.—A LEAF-CUTTER BEE AND ITS NESTS

We have already mentioned (Chapter XL) the thread-waisted female that was observed finishing her hole by pounding with a pebble held as a tool between her jaws.

Leaf-Cutter Bees.—A number of the solitary bees are leaf-cutters, lining their nests with bits of leaves and of more brilliant flower petals. Some of the cutter bees use the cottony fluff gathered from the seeds of such flowers as the thistle and milkweed. Some use gum or resin, or the sap of other plants. One bee placed 1,064 bits of leaf in a single cluster of nests. One species lines her nest and then builds a honey pot with a lid, using in each structure bits of leaf carefully cut to shape for the particular need.

The only difficulty is that the leaf-cutter mother has no means of fastening the walls together; but the larva, some time after it has hatched, secretes a liquid silk which glues the leaves in position.

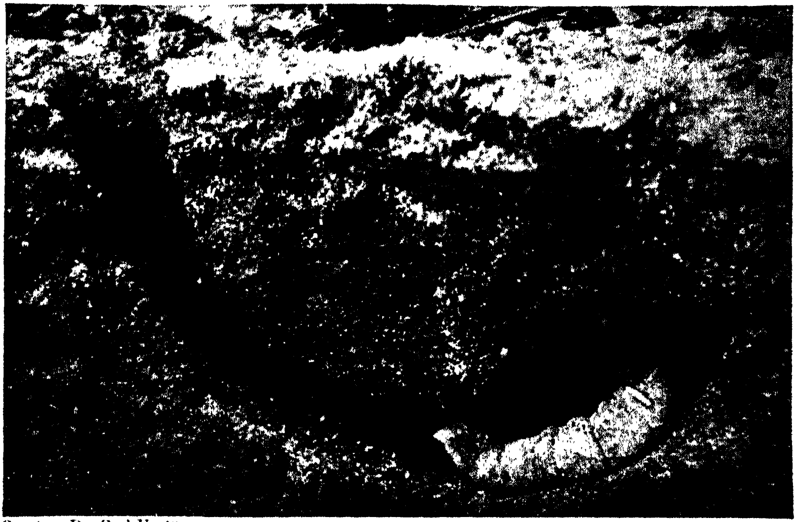
Mother Solitary, having provided for her offspring, now deserts it. She may build twenty or thirty other cells before her instincts are satisfied, and then the rest of her brief life is spent in visiting the open fields, where she banquets on nectar and pollen, and spends hours flying in the sun, racing and dancing with others of her kind. But she soon grows exhausted and dies, usually before her offspring have ever seen daylight.

The Next Generation

Back in the nursery the egg is hatching. Not unlike a human babe, the youngster's mouth is a machine made to suck whatever it touches. It will suck air if nothing better offers, but the ready-to-hand dish of meat is more attractive. Like children eating the plums out of a pudding, baby wasp is liable to consume the abdomens of her victims before she touches their less attractive parts. As a result, the victuals are allowed to live for some time after they are served up as food.

To be truthful, we must admit that the efficiency of the paralyzing stroke which Mrs. Solitary deals her victims is not always perfect. Sometimes the blow kills immediately. Sometimes the prey recovers completely within a few days, and then the poor infant Solitary is born face to face with an awful ogre. But usually the paralyzed prey live from three to thirty days after paralysis sets in, and that is sufficient to guarantee fresh food to the larva throughout its feeding period.

The Potter Wasps.—Some of the little potter wasps are apparently unable to paralyze their prey sufficiently to make it safe to lay eggs in their midst. So the egg is suspended from the ceiling of the mud jug, while the caterpillars pile up on the floor. When the young wasp hatches, it adds a silken sheet to the eggshell, and down this it climbs to take a bite of breakfast. When the breakfast objects too strenuously, the larva withdraws to the safety of the ceiling, there to await a moment propitious for another attack.



Courtesy Dr. Carl Hartman

FIG. 464.—THE NEST, PREY, AND EGG OF THE SOLITARY WASP

During all of the larval life of most of these solitary wasps, there is no excretion of waste materials from the intestine. That would dangerously soil the interior of the cell and hasten the death of the food material. Just before the insect becomes a pupa it excretes all of the stored-up waste. It may place this in a single spot removed from the rest of the nest; or it may cover the excrement with silk or earth; or it may use the material (often reënforced with silk) to build itself a cocoon.

The Emerging Insects.—Pupating in this cocoon, in some days or weeks the insect matures and emerges. Now, for the first time in all of its history, it is inspired to dig out of its prison. The tunnel which originally led to the chamber offers no trace of help, for it has been too carefully filled by the mother wasp. The young creature must dig and chew through solid earth, sometimes for a foot or more, softening the mud door with saliva, until finally it bursts into the dazzling brightness of the sunshine. It is not impossible that you may happen upon one of these eruptions in the course of your ramblings in the fields.

Where several cells are connected in a chain, the oldest egg, and therefore usually the first to hatch, is the one farthest removed from the open air. In an underground nest, or in one in the stem of a woody plant, where the oldest wasp would be likely to endanger its brothers and sisters as it dug out, the first-born is for some reason satisfied to stay entombed until the way is cleared for it. There is even evidence that the first egg laid is sometimes the last to develop into a mature wasp, and that the last egg laid develops first; and thus there may be a peaceful and easy emergence for all of the family.

The male wasp usually matures first. It is about and actively hunting the female for some days before she comes out of the ground. Her eyes have hardly greeted the sun before she is caught up by a male who mates with her. With only few exceptions, the males then disappear from the scenes, leaving the females to conduct the rest of the drama.

Colonies of Solitaries.—We have said that the mother Solitary does not live to know her own offspring. There are a few exceptions to this. In one case the mother stays by the old hole until her daughters appear, and even until she has become a grandmother. The young bees build their cells as additional branches from the old family gallery, using the entrance which their mother first dug. While her daughters are building, provisioning, and populating the nurseries, the bald-headed grandmother, the hairs of her head worn off by her springtime labors, sits in the doorway, her tiny face an effective block to all would-be intruders, the force of her jaws and sting still sufficient to drive away even bold marauders. This species of bee has two generations a year, and it is in the fall that the two live together. After that all of the old ones die, and the next generation emerges in the spring without the company of its relatives.

The Behavior of the Solitaries

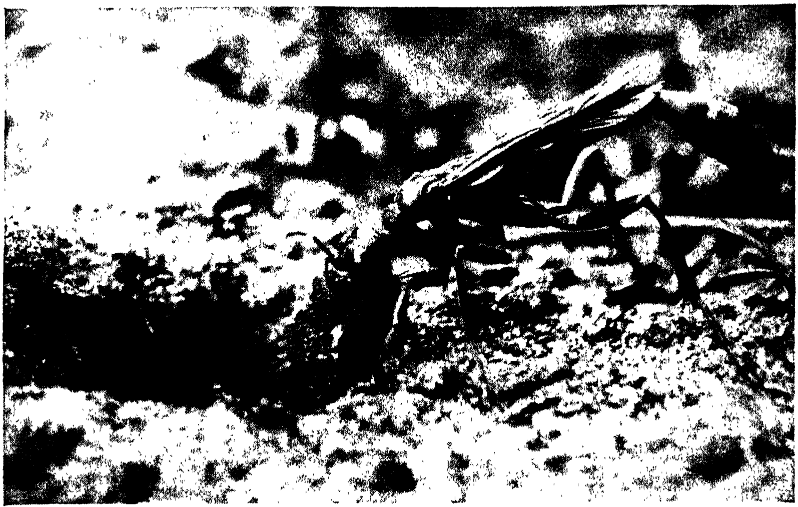
Can we explain the incredible behavior of these tiny insect folk? Can we label each act as tropism or instinct or memory or some other proper thing?

That task would require more time and further observations than we possess. Nevertheless, it seems correct to say now that the activities of the solitary wasps and bees may be analyzed as simply as the behavior of any of the other insects we have studied. Only a few explanations of this can be given here.

Instincts.—Much of the behavior clearly consists of such chains as we have called instinct. Each particular performance regularly supplies the cue, and the only cue, which will bring on the next. One cue may lead to a performance which is the exact opposite of something that the insect has done earlier.

There is no doubt that much of this behavior is mechanical. If the nest of a solitary be systematically robbed as the prey are placed in it, the wasp detects no difference. Even when her last inspection leads her into an empty nest, the fact that she has previously carried in enough provisions may be the sufficient cue, and she goes ahead and seals the chamber with all the care she would bestow on a properly provisioned one. We have already pointed out (Chapter XXXIX) how easy it is to supply the wrong cue at any moment and make the wasp repeat its steps a number of times.

But if instincts dominate, it should also be noted that there is considerable variation in the workings of these among the individual wasps of the same species. Some paralyze their victims precisely; others make a bungling job of it. Some dig deep; others dig only scantily. Some perform the whole chain in proper order; others make mistakes and may, for instance, promptly close up a cell the very moment after they have dug it, and before they have stored either provisions or eggs. It should not be forgotten that each and every insect machine has its imperfections and is not so regular as our summary accounts would indicate.



Courtesy Dr. Carl Hartman

FIG. 465.—FILLING THE ENTRANCE TO THE NEST

Memory.—Moreover, it may be that some of the behavior which we have called instinct may be better explained as the result of memory. It is certain that considerable memory intelligence is displayed by these insects. On an earlier page we have described how they remember landmarks which they use as guides for locating their homes. They have been known to find their way a mile from their nests.

Reasoning.—These wasps, more than any other insects, have given clear evidence of reasoning intelligence. We have considered the behavior of the solitary wasp that enlarged its hole to accommodate a certain spider, and of the other solitary that used a pebble as a tool to pound down the dirt in its nest. As still another instance, we might mention the wasp that located her nest between two railroad tracks and then paid no attention to any landmarks except the tracks. After foraging, she would return directly to the track, no matter how far to one side of the nest that was, and then she would follow the track home. How was it that she chose to remember and use the tracks, among all of the landmarks that might have been selected? Her choice of the most useful landmark in the neighborhood seems to have had something of reasoning about it.

Nevertheless, it must not be thought that it is possible to explain every particular instance of wasp and bee behavior. There is, for example, the case of the Solitary that builds her nest in the banks of streams, well up above the water level. The prey she seeks is a large spider, one that is several times her own weight, and such a one as would make a tremendously difficult burden to drag home through the grasses and weeds. So the wasp rolls her spider into the stream, where, helped by the buoyancy of the water, it is not too heavy a load to manage. Setting her wings a-going, her legs trailing the spider behind her, she sails like a tiny hydroplane along the watercourse to a point below her nest, and from there the rest of the journey is not too difficult. How the wasp ever learned the value of floating a heavy load is beyond my present attempts at explaining.

As one observer has concluded, it is very much of a question whether these "wasps are wiser than they seem or seem wiser than they are."

SUMMARY

1. Among the most remarkable of all insects are the solitary wasps and bees. There are some ten thousand species, each with its own peculiar ways. The mud-daubers are typical of the group.

2. The solitary wasps and bees are so called because they are not social, the adult insects not living in the nests which they have built for their offspring.

3. The mud-daubers build nests of mud and stock them with paralyzed spiders on which the young wasps may feed. The female does most of the nest-building. The male mud-daubers, unlike the males of most wasps, do some of the work too.

4. The solitary wasps feed on insect or spider food which they paralyze. The solitary bees make a pollen and honey paste for their young. Each species uses a particular kind of food, being expert at finding and capturing that particular food. Soft-bodied food is placed in damp soil.

5. The solitary wasps nest in holes in the ground, in cracks and crevices in walls and old buildings, or in earthen cells. Usually each species chooses a particular sort of place for its nest. Solitary bees build in similar places, and also in hollow stems of plants or in old logs.

6. Nests in the ground are dug with the insect's legs and jaws, the adults sleeping in the unfinished nest the first night, finishing the nest the next day. They gather provisions only after the nest is built, temporarily closing the nest if they have to leave to get additional provisions. The egg is deposited last. The hole is re-filled with earth and usually left with no sign that the place was ever disturbed. Some of the solitary bees are leaf-cutters, their larvæ fastening the pieces of leaves with silk.

7. Some of the larval wasps have special ways of feeding: *e.g.*, the baby potter wasps hang from silken ropes while they nibble into the actively live food material. During larval life no excrement is cast to soil the interior of the nest. If several cells are in a row, the insect from the last cell built is the first to emerge, the insect from the first cell is the last to emerge. Emergence is thus accomplished without harm to any of the insects.

8. Even these remarkable doings of the solitary wasps and bees are chiefly mechanical types of behavior, chiefly chains of instinct. There is, however, considerable individual variation in the way they behave, some of them performing more mechanically, some more inefficiently than others.

9. Memory is remarkably well developed among these insects.

10. The only cases of apparent reason among insects are found in these wasps. The wasp which used a pebble as a tool to pound down the dirt in its nest, and the wasp that used the railroad tracks to guide her to her nest, seem to have shown some reasoning intelligence. But it is difficult to say whether these wasps are wiser than they seem or seem wiser than they are.

PROBLEMS

1. What good is it to know something about these solitary wasps and bees? Are they of economic importance? Then is it worth while learning about them?

2. Have you ever seen the nest of a mud-dauber, or of any other solitary wasp or bee? What did you observe about it?

3. What four or five things will you remember as most interesting in the behavior of the solitary wasps and bees?

4. If you were allowed only one way of further studying these insects, which would you choose: to make a collection of as many kinds of solitary wasps and bees as possible; to read a number of the books that have been written about these insects; or to carefully observe the behavior of a live solitary wasp or bee of some particular species? Why do you make your choice?

5. Discuss: Are the wasps wiser than they seem, or do they seem wiser than they are?

6. Find out something about the life of Henri Fabre, Phil Rau, or other observers of the solitary wasps and bees. Report to the class.

7. What are the qualities which an observer of insects must have in order to make first-class contributions to our knowledge of insect behavior?

8. By what structures could you distinguish a solitary wasp from a social wasp? Compare figures in this book, or (better) compare insects in a collection.

9. Make a list of the most important differences in behavior between a solitary and a social wasp.

10. What similarities are there in the behavior of the solitary and the social wasps?

11. What things does a mother solitary do, instinctively, that are advantageous to her offspring but not to the mother herself?

12. The solitary wasps are temporary parasites. Compare the advantages of temporary and permanent parasitism.

13. Read about solitary wasps and bees in some of the reference books listed in this chapter or at the end of this Unit, and briefly report to the class.

14. Why are we giving animals more attention than we give plants in this Unit in our biology course?

CHAPTER XLV

BIRD BEHAVIOR

You may spend some delightful hours in studying the bird world.

Bird Study

Sometimes they will be early morning hours, perhaps in the dusk before dawn, when you will want to bundle in warm clothing as you go forth to observe the first activities of the day; or they will be later hours after sunrise, but before the heat of the summer day has driven the bird world to cover. Sometimes they will be mid-day hours, when you will lie on your back and use a field-glass to scan the tops of the tall trees, or when you will watch a hawk or an eagle as it climbs into the blue.

Sometimes they will be twilight hours, when the birds of the daytime are hushing their songs, and the veery thrush will ring out its noisy spiral of tumbling notes, and the white-throated sparrow will whistle its plaintive call, and the first soft notes of the owl will herald the night.

You will find such experiences among the richest this world can give. And whether you can roam in broad fields and woodlands, or must explore suburban gardens or city parks, the birds are yours if you will go after them.

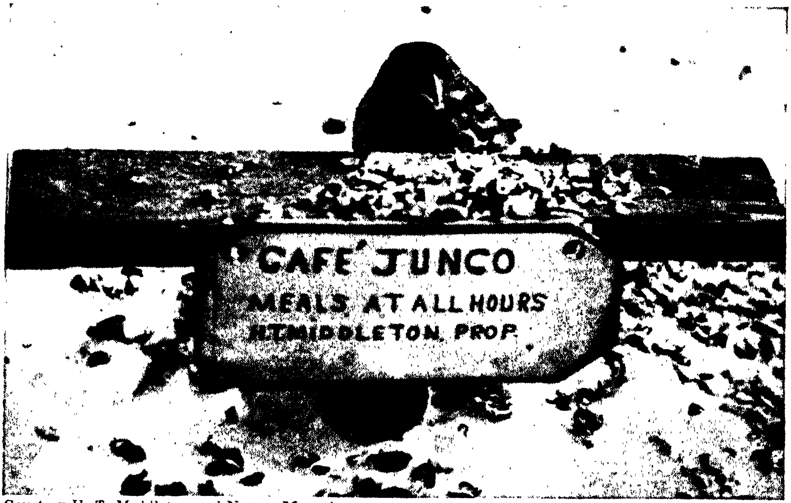
Things to Observe.—But you must take a lot of patience along with you, for these are timid creatures you are trying to see. They need to be stalked with the skill of a hunter. You cannot escape a bird's keen eye, and you must depend upon your ability to approach without frightening the creature. Walk slowly and *move evenly*. Use a canoe if you are near water, and then you may paddle so noiselessly and move so evenly that you can get within a few feet of the wildest creatures.

If the bird flies quickly as you approach, have your eye and your brain alert, and in the moment try to get a clear notion of the bird's size (compared with that of a robin or an English sparrow), of the shape of its bill (if you are near enough to see it), and of its color markings, especially those on its breast. You should be able to see these things with your unaided eyes. Though field-glasses are an additional help, they are not necessary. You will see the most birds and make the most interesting observations if you are alone when you set forth to study these creatures.

FIG. 466.—EARLY MORNING BIRD-STUDY

After your first observation, you may have a chance to see the same bird again and in time accumulate a more complete notion of its markings. You may be able to note something about its song and its call notes, see what is peculiar about the way it flies, and perhaps locate its nest. With such information, you should be able to find your bird mentioned in some bird book, and learn its name, and feel that you have really added to the list of your acquaintances.

Conservation.—It is delightful to attract birds to your own yard, where you may observe them in intimate detail. You may do this anywhere, except perhaps in the heart of a city. A shallow pan constantly supplied with water, and placed on or above the ground in the open where skulking cats cannot too easily approach, will bring birds to drink and to bathe.



Courtesy H. T. Middleton and Nature Magazine

FIG. 467.—A SONG SPARROW AT THE FEEDING STATION

Food regularly placed on feeding-shelves that offer some protection from severe weather, and again from the cat nuisance, will bring regular visitors, some of whom perhaps will become so tame that you may have the thrill of touching them while they feed. Sunflower, melon, and pumpkin seeds, and indeed any coarse seeds, oatmeal, peanuts, popcorn, pork rinds, and fat or suet are suitable for the bird feeding-table.

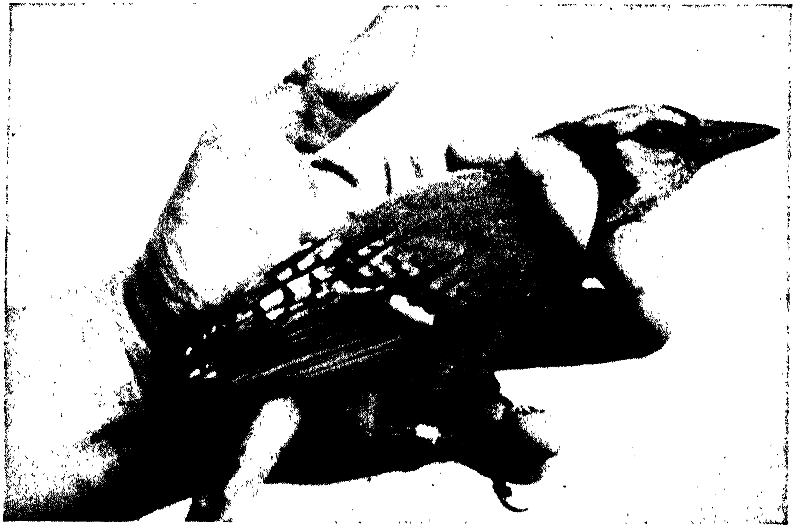
The planting of shrubbery about your home, especially of species that produce attractive berries (including such wild shrubs as sumac, elder, red cedar, wild cherry, hawthorn, black alder, bittersweet, Juneberry, mulberry, yucca, and wild roses), will provide food and nesting places for many kinds of birds.

Certain of the species may be attracted to nesting boxes that are put up for them. Wooden boxes, large tin cans, things made from bark, sections of hollow tree trunks, and other contrivances will suffice. Wrens, bluebirds, some of the swallows, and perhaps woodpeckers may be expected. Robins will nest in open boxes or on flat shelves placed in protected places. Martins require a compartment house designed for a whole colony. English sparrows will pre-occupy everything unless you promptly and regularly tear out their nests and drive them away. Boxes suspended with rope sometimes discourage these pests without interfering with the use of the nests by the native birds. In every case be certain that cats cannot climb to the home you have encouraged.

Bird-Banding.—This is a recently developed method of study. Small aluminum bands are placed upon the legs of nesting birds or of adults caught in cages at feeding-stations. Then the birds go free, none the worse for their experiences. The United States Biological Survey supervises this work, issuing the bands to responsible adults. If a banded bird is ever again taken at the same or another station, the number on its leg band serves to identify it. Comparison with the Government records then shows whatever else is known about the individual, perhaps where it was hatched, how old it is, where it has migrated, and other such things.

The bird-banding work is greatly increasing our knowledge of the intimate lives of birds. Mallard ducks banded in Illinois have been recorded from twenty-one states and provinces, from Florida and Texas to Saskatchewan. A certain brown thrasher was recognized at its old nesting site for eight years in succession. A tern banded in Maine was picked up on the African Congo. Perhaps you may have an opportunity to observe or even to help some grown-up who is engaging in such work.

An enthusiastic friend writes: "You will be interested to know that a nighthawk has returned for four successive seasons to build her nest on our high school roof. A Biological Survey band identified her. The bird became so tame that I handled her freely. Think of that nighthawk migrating those thousands of miles each year to South America and then returning to our roof!"



Courtesy S. Prentiss Baldwin

FIG. 468.—BLUE-JAY WITH A LEG BAND

Perhaps you perceive something of the life-long pleasures that may be yours if you once get started in bird study.

Habitats

If you would become acquainted with the greatest number of birds, you will have to go into the many different kinds of habitats which they frequent.

Many birds live only in the open fields and on the prairies, where they nest in the low bushes and on the ground and feed upon weed seeds and ground-inhabiting insects. Others, more shy species, take to the deep woodlands, where some of them nest on the ground, and some of them nest in the branches of the trees, but where most of them are insect-feeders that are usually so active in hunting food that they are not easily observed. Some birds, the more pugnacious, able to defend themselves against the attacks of any bird, larger or smaller — such birds as the humming-birds, the king-birds, and some of the hawks—dare to place their nests on exposed ends of protruding limbs, often on solitary trees in open fields and pastures. Where sheer cliffs stand out in high mountain country, one may look for the bald or golden eagles. In the typically northern life zones of such mountain

Painting by Bruce Horsfall. Courtesy Nature Magazine

FIG. 469.—THE WATER OUZEL AND ITS PREFERRED HABITAT

country, one may find an entirely new list of bird species, including an occasional visitor from the Arctics themselves.

The student of birds will, sooner or later, find himself in as many kinds of country as there are, and this is not the least among the pleasures of bird study.

The shores of streams, of ponds, and of lakes, and the ocean coasts are more effective than other habitats in attracting birds, especially if their shores are swampy. Birds are drawn by the opportunity for bathing, and such places also offer an abundance of seed and insect food. The open waters of the lakes and of the ocean furnish attractions for only such special kinds of birds as gulls, terns, ducks, loons, and grebes.

Most birds when afforded some measure of protection adapt themselves to the conditions of our civilization and take up their abodes in our fields, our gardens, and shade trees. The robin, the wood thrush, the jays, and the crows are among the birds that find conditions near our towns more attractive than the open country. A few birds, including not only the English sparrow, but several of the swallows, the chimney swift, the phœbe, the house wren, and the bluebird as well, often utilize man-made structures in locating their homes.

Each kind of bird is usually confined to a single kind of habitat. Inherited instinct probably has something to do with such behavior. This will be evident to you if you remember that ducklings take to water even when hatched in the nest of a hen. But it is also evident that the foods found in a habitat provide its chief attraction for the birds.

Foods

The greater part of the activities of a bird, from before dawn to sunset, are concerned with the gathering and eating of food. Only during the hotter parts of the summer day, and during sleep at night, do the birds ordinarily stop active feeding.

Special and General Feeders.—Most birds are special feeders, confining themselves largely to a single kind of food.

For the sparrows and finches it is weed seeds, for the warblers and vireos small insects, for the woodpeckers wood-inhabiting insects, and for the hawks and owls larger insects and vertebrates.

A smaller number of birds, like the robin, the thrushes, the catbird, and the mocking-bird, are general feeders, eating seeds, berries, fruits, insects, and perhaps worms, as the season offers.

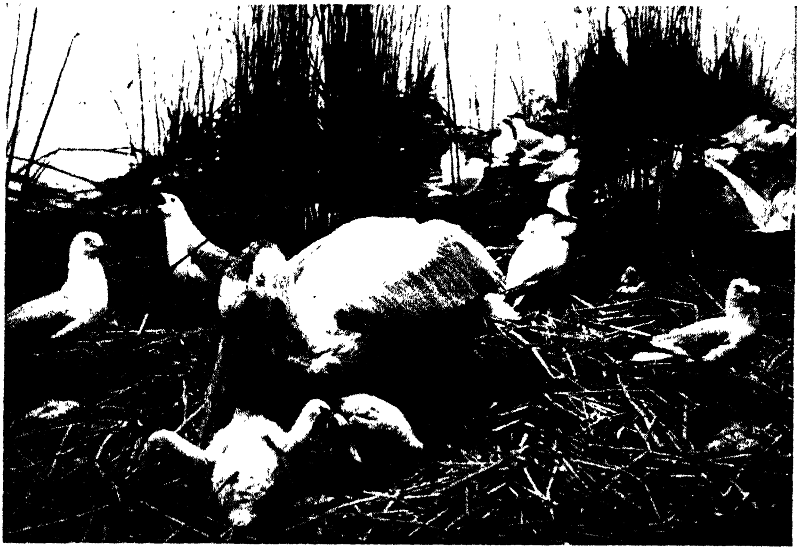

Courtesy Amer. Mus. Nat. Hist.

FIG. 470.—PELICAN FEEDING PARTLY DIGESTED FOOD TO ITS YOUNG
Bird nesting grounds at Klamath Lake, northeastern California.

Use of Bills.—All birds, except the hawks, the eagles, and the owls, take their food with their bills, and the structure of the bird's bill largely limits its diet. The broad, conical beak of a sparrow is well adapted for crushing weed seeds, but it is not a good tool for picking tiny insects from behind bits of bark. The slender, finely pointed bills of the warblers and vireos are the ones designed for collecting small insects. The feet of the hawks and owls are heavy and powerfully clawed for capturing big game and tearing it to pieces.

Use of Wings and Tails.—The nature of a bird's wing may help determine what the bird eats. Wings that are good for only heavy flight restrict a bird to the foods of the open fields and prairies. Wings that may be used for prolonged flight and for soaring and for diving allow their owners (swallows and swifts) to feed on insects in mid-air. The swift wings, small bodies, and high nervous tension of many insect-eating birds (warblers, vireos, chickadees, flycatchers) are aids to catching insects that must be pursued through the tangled branches of trees.

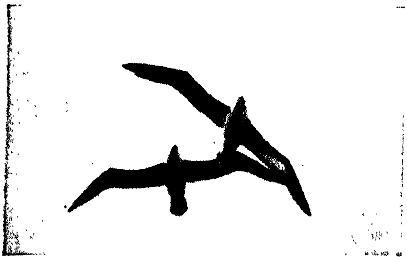


Photo R. C. Murphy
Courtesy Amer. Mus. Nat. Hist.

FIG. 471.—ALBATROSS SOARING

Some of the birds, such as the cuckoos, the thrashers, and mocking-birds, have long tails that serve as rudders in broken flights into dense bushes after food.

The blunt bills and bone-tipped tongues of woodpeckers aid in their exploration of hard wood.

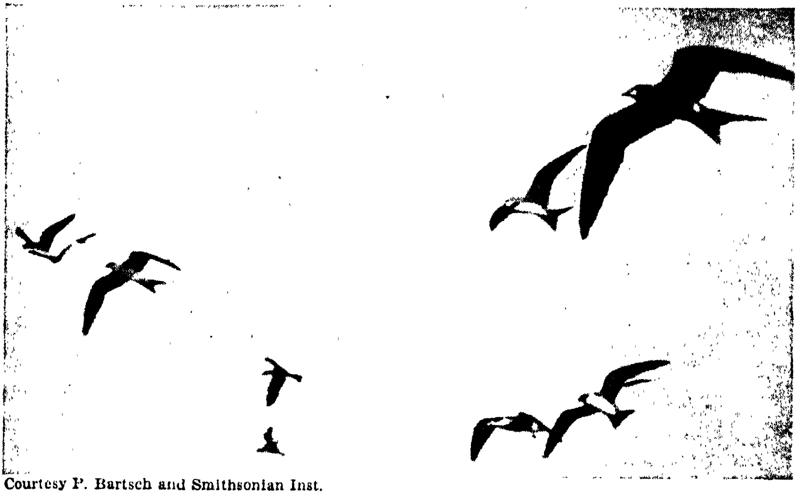
Evidently the feeding behavior of a bird depends chiefly upon its structure; and the structures seem to be adaptations to the feeding behavior. The structures and the behavior have probably developed together in the course of evolution.

Flight

Birds fly primarily for the sake of finding food or to escape enemies.

Birds like the bob-white and the grouse and the closely related domesticated chicken never make more than short flights; but other birds (swallows, hawks, eagles, and buzzards) may spend most of their time in the air. The chimney swift may fly for twelve or fourteen hours at a time, never resting from dawn until after sunset.

Wing Structure.—A bird's wing is very large compared with the rest of its structures. Its feathers, its hollow bones, and its great air-sacs containing air well heated by the blood may make the creature more nearly the weight of the air in which it flies.



Courtesy P. Bartsch and Smithsonian Inst.

FIG. 472.—SOOTY TERNS IN FLIGHT

Long, slender, curved wings seem best for rapid flight (as with the terns, swallows, and swifts). Broad wings seem best for soaring (most hawks, martins, and buzzards).

The rate at which a wing moves does not appear to have much relation to the speed of the bird or its endurance in flight. The long wings of a tern stroke slowly, but its speed is as great as or better than that of the chimney swift that strokes rapidly.

The ability to spiral and to soar straight upward into the air is still one of the unexplained things about bird flight. A hawk, a buzzard, or an eagle that has reached a height of a few hundred feet may spread its wings and hold them apparently motionless while it continues to rise upward in a small spiral. It is a remarkable performance that is worth watching.

Differs with Each Species.—The flight of each species of bird is as typical as its colorings. Just as each of your human friends may be identified by his peculiar manner of walking, so you may identify each species of bird at a considerable distance by the characters of its flight.

The robin flies in a straight line with its wings stroking regularly; the cedar waxwing flies almost as directly, but it misses every fourth or fifth stroke. The chipping sparrow flies in darts with an insect-like flutter which perhaps you will have to see before you will understand what I mean. The song sparrow flies with its body tilted upward, and continually jerks its tail up and down like a pump handle. Similarly, every other bird has a distinctive method of flying. There is very little on this subject in the books, but you may have your own fun watching the birds and analyzing their flight until you come, bit by bit, to know what is peculiar for each species.

Inherited Ability.—These creatures are not taught to use their wings. Orphaned baby birds that are raised by human hands will some day pick up and fly away. The structures of a bird are inherited tools that run all right when they become well enough developed.

Nevertheless, the older birds do much to encourage the younger ones to fly. Sometimes the parent birds push the young out of the nest when they become old enough to use their wings, or the babies may be starved until they leave the nest.

Songs and Call Notes

The songs of birds are remarkably attractive and interesting. You must come to know them. It is as well, perhaps, if you have no one to help you in this part of bird study, for then you may have the fun of chasing the songs you hear until you see each singer.

Songs.—Each species has its own peculiar song. A few birds, like the goldfinch, have flight songs that differ from the notes given while at play in the tree-tops; but most birds have only a single tune, and this you may come to know as typical for each species.

There are only a few birds (king-bird, chimney swift, cedar waxwing) that have no true songs.

Most birds sing best at the mating season, and then it is usually the male which is more gifted. Many birds stop singing after the nesting season is over, and only a few (the song sparrow for instance) sing well throughout the year.

Most birds sing most actively in the early morning, but a few (the hermit thrush, veery thrush, white-throated sparrow) sing best in the twilight immediately after sundown, and a few (the whip-poor-will and most of the owls) sing only at night. Some of the daylight singers may be heard occasionally at midnight, when the broken phrases of their songs make one believe the birds are asleep as they sing.

Call Notes.—The call notes of birds express their emotions, such as fear when danger threatens, or anger when rain or the cat or something else causes a disturbance. They also serve to attract other birds, and they are regularly exchanged between the parents and young and between birds in migration. A few birds, like the robin, possess several different kinds of call notes, each apparently useful in its own particular way.

In addition to recognizing the species of a bird by its song or call note, it is possible to know individual birds by their individual notes. No two individuals of a species sing quite alike. If you come to know the peculiar song of each bird in your neighborhood, you may tell its whereabouts at any hour of the day, and follow it for days and for months in succession. Such intimate acquaintance with birds is delightful.

Hereditary Basis.—While each bird inherits a throat structure that is peculiar to its species—a crow could never in the world carol like a robin—each individual bird develops its song only after practice. It may be many months old before it can sing like its relatives, and meanwhile its efforts are sometimes ludicrous.

The perfection in a bird's song may be due in part to its ability to imitate its fellows. While the mocking-bird, brown thrasher, and catbird are peculiarly noted for their imitations, many other birds show something of the same ability.

The Daily Program

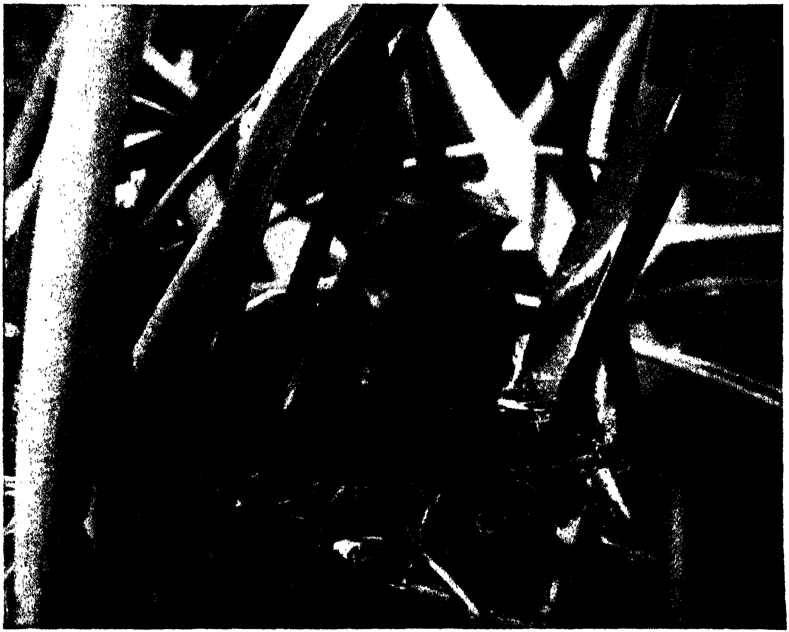
The bird's daily program is a round of feeding, flying, singing, and sleeping. Birds are up an hour or more before sunrise, and are then more active than at any other time of the day. By sunrise they are busily engaged in feeding and have quieted their songs somewhat. There is another burst of activity an hour or so after sunrise. From then on to sunset the birds become less and less noisy and less active. At sunset and in the early twilight most birds fly about a good deal and a few of them again burst into song.

But soon all the smaller birds seek out protected nooks in bushes and trees, in clumps of evergreens if they are available; and taking tight hold of some twig that is close to the shelter of a main branch, they go to sleep for the night. Then you may approach with a lantern and do considerable thrashing about in the brush without disturbing them.

Restricted Range.—In the course of a day most birds stay close to a single spot. This is usually the nesting site, even after the nesting season is past and the bird no longer sleeps at home. Perhaps a hundred-yard radius would represent the daily range of most of our smaller birds. Many things, such as enemies, food shortages, and especially attractive foods, may lead them beyond their normal ranges, and in the migration season, of course, they travel thousands of miles.

The available food supply usually prohibits more than a few nestings of each species in any one region. On the other hand, there are some birds (martins, swallows, and waxwings) that always nest in colonies of good size.

In Rain Storms.—A bird is a peculiar creature in a rain storm. While its feathers will shed water for a time, prolonged wetting soaks them and reduces their efficiency in conserving the body heat. Consequently most birds take to the thick shelter of bushes and trees at such times. Only a few of them (as the robin) stay out and scold at warm rains, and a few of them (as the song sparrow) remain quite as active and cheerful as in the sunshine. In storms that last more than a day all the birds are forced out to hunt food, and then they are a songless and bedraggled lot until the sun again shines. Parent birds usually keep their nestlings covered during a rain storm.



Courtesy R. B. Rockwell, Denver

FIG. 473.—UP BEFORE SUNRISE
Young yellow-headed blackbird, Colorado.

Molting.—The normal routine of the bird's life is interrupted when it *molts,* as we say, at which time it loses its feathers and grows new ones. While a few species may molt oftener, most birds molt twice a year, once in the spring just before they start north in migration, and once late in the summer just before they start south.

In molting, many of our birds have their old feathers drop out one by one while the new ones are growing in. During the process, the bird is usually inactive and shy, and it may withdraw into the deep woodlands and live the life of a hermit at such seasons.

The fall plumage of a bird is in many cases quite different from its spring clothes.

The Nesting

The first birds to come back in the spring are usually males. Some weeks later the females of the same species arrive.

After the mating, each pair of birds sets to work to find a nesting site and to build a nest. For some birds this occurs in March, and with others not until August, but most birds nest in the late spring. Some of them (robins, catbirds, song sparrows, wrens) may have two or three nestings in a single year, and then the last family cannot be raised until late in the summer.

Some birds stay mated throughout the year; others are fickle and change mates several times in a season. A few species are said to mate for life, but this is not proved.

Both male and female birds may engage in the building of the nest.

Nest Materials.—The materials that they use are usually grasses and finer weed stems, but heavier sticks, bark, paper, cloth, string, mud, hair, and other things may be used. Within a single nest the materials are usually of a uniform color and texture, and great skill is often shown in avoiding things that do not fit into the architectural scheme.

The inside lining may be distinct from the rest of the nest, for it is the bed on which the baby birds lie, and it is fittingly made of extra-fine materials. Goldfinches use thistle-down, chipping sparrows and some others use horse-hair, one of the flycatchers uses snake skins (!), and the robin uses fine stems with a layer of mud beneath them.

Form of the Nest.—Using their bills and their feet, the birds weave their nests as a basket-maker would work, and tie and press their materials into shape.

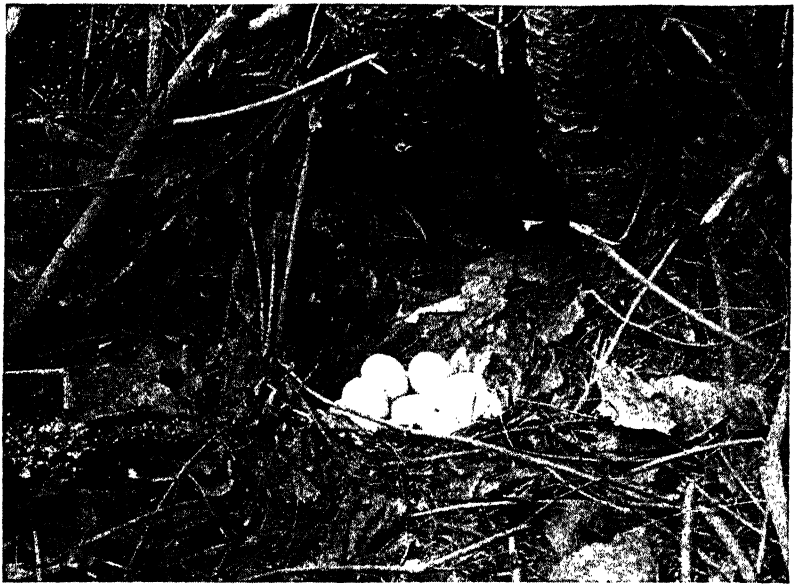
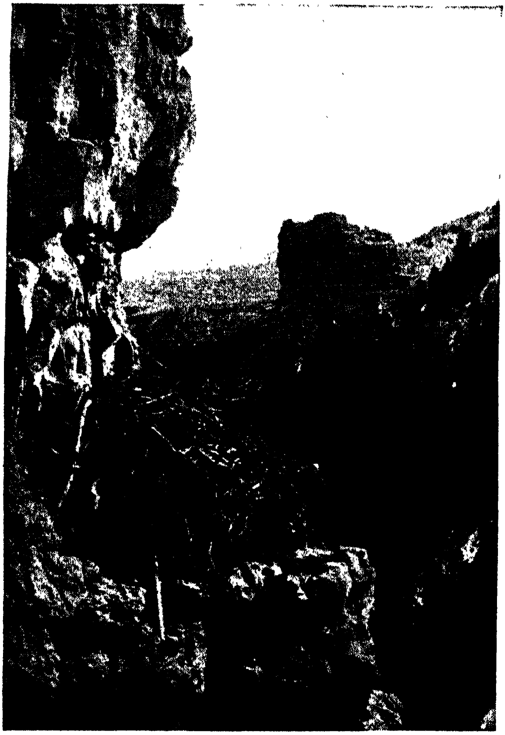


FIG. 474.—NEST OF RUFFED GROUSE (PARTRIDGE), MAINE

The shape of the nest identifies the species of bird that has built it. It may be a flattened bowl (as with the robin), or a beautifully hemispherical cup (as with the vireo), a cleverly woven hanging basket (as the Baltimore oriole uses), or a loose and disorderly collection of twigs (as with the dove). Some birds (the whip-poor-will and gulls) merely use hollows worked out on the ground. Even closely related species of birds will have distinctive nests.

Location.—In locating its nest, each species of bird has its own preferences. The oriole seeks the tip-end branches of a tall tree, the robin locates on some solid base that is not too far above the ground, the red-eyed vireo hangs its nest from the forked branch of a tree, the song sparrow goes to the tangle of some low shrub, the meadow-lark builds on the ground, and the junco buries its cosy home under a clump of moss or in loose earth itself.



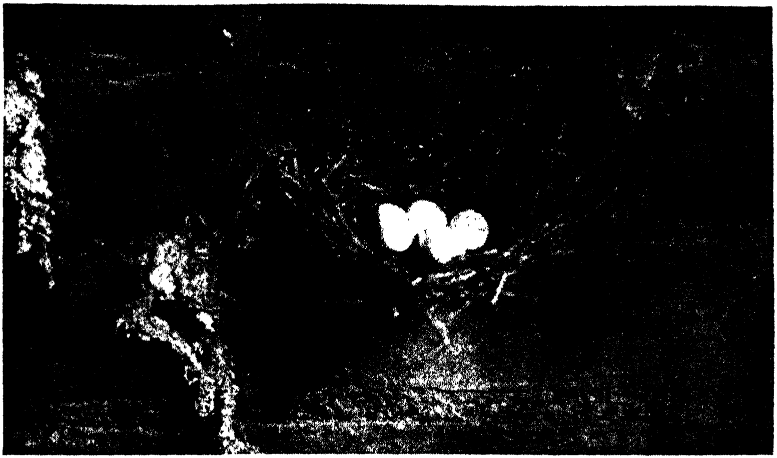
Courtesy Amer. Mus. Nat. Hist.

FIG. 475.—THE HOME OF THE GOLDEN EAGLE—WYOMING

The bluebirds and woodpeckers live in holes in trees. The phœbe, the house wren, the barn swallow, and the martin prefer the beams of houses and barns or the boxes put up for them by man. So strictly does the barn swallow now depend upon human aid that we wonder where it nested a few centuries ago, before barns were first built on this continent.

Raising the Young.—After three or four days of work, the nest is completed and the female begins laying eggs. While three or four are the average for a nesting, the whip-poor-will lays only two, and the bob-white may have thirty or more.

In many cases the male and the female birds take turns at



Courtesy L. W. Brownell

FIG. 476.—THE CHIMNEY SWIFT'S NEST
Fastened with saliva to the inside of the chimney.

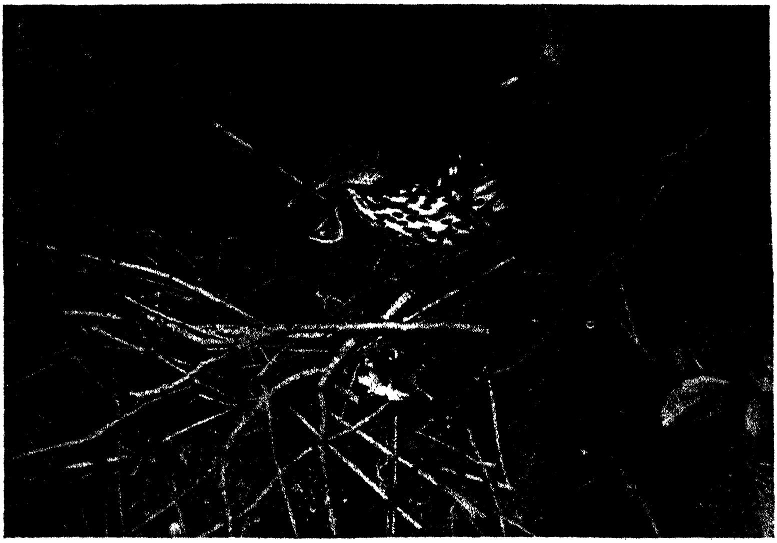


FIG. 477.—BROWN THRASHER ON NEST

incubating the eggs. Within ten or twenty days, varying with the species, the eggs begin hatching.

Most birds (robins, sparrows, etc.) are naked and blind when they break their shells, but in a few days they open their eyes and grow down feathers. The young of ground-inhabiting birds (as the chicken and bob-white) and water birds (sandpipers, ducks, gulls) are feathered and quite able to walk or swim within a few hours after they hatch.

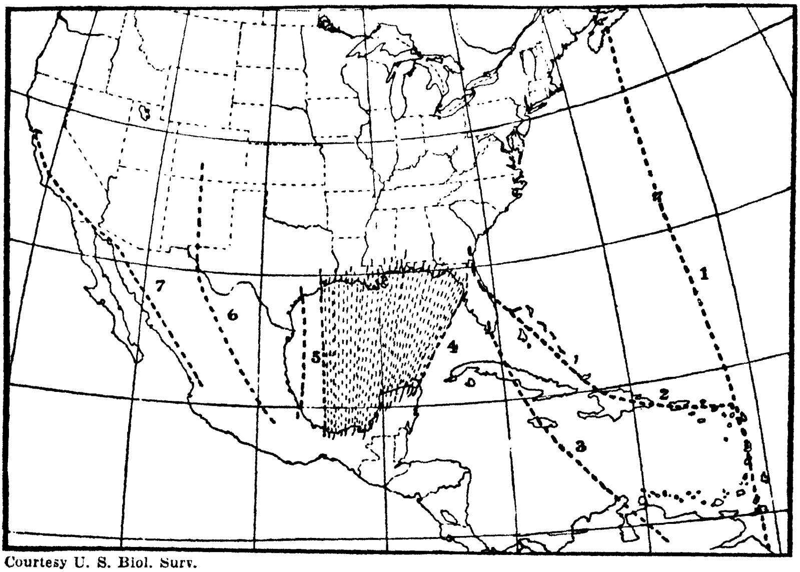
Courtesy R. B. Rockwell, Denver

FIG. 478.—YOUNG BLACK-CROWNED NIGHT HERONS, COLORADO

These nesting activities are so clearly mechanical chains of behavior that we used them as the introduction to our study of instincts. Each bird goes about the building of its nest in much the same way as its ancestors did, choosing the same kind of location, the same materials, and the same architectural plan. While each individual bird may have its activities modified by experience, the basis of the nesting behavior is instinctive and not intelligent.

Migration

One of the most remarkable things in animal behavior is the annual migration which birds make between their summer homes and their often remotely located winter homes.



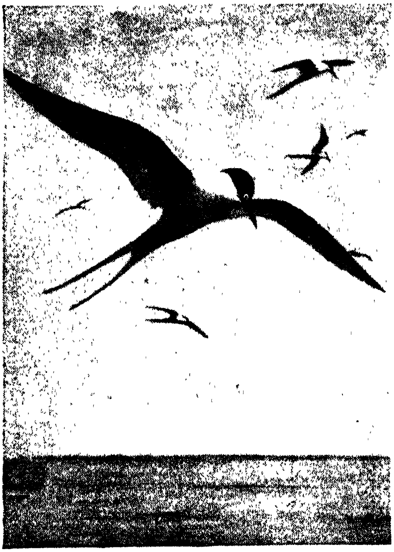
Courtesy U. S. Biol. Surv.

FIG. 479.—PRINCIPAL MIGRATION ROUTES OF NORTH AMERICAN BIRDS

In this migration, some birds (as the warblers) merely straggle along for a few miles each day, feeding as they go. Most birds make their migration a direct flight broken by not more than one or two stops for feeding.

Some of our birds go only a few miles southward as cold weather approaches, and do not go beyond the limits of our southern states. However, many of the birds of the northern United States and Canada winter in the northern parts of South America. The champion long-distance migrant is the Arctic tern. It nests in the Arctics of North America, and winters in the Antarctics far south of South America, making a round-trip of over 22,000 miles in migration each year!

Only the larger birds that have the swiftest wings migrate by day. The smaller birds that are weaker fliers migrate mostly at night, when they have least to fear from their enemies. Often on a fall evening you may hear the calls of many birds travelling southward, a thousand feet or more overhead. If you will look at the moon on such a night you may see the birds as they cross the path of the light.



Drawing by L. A. Fuertes
Courtesy U. S. Biol. Surv.

FIG. 480.— ARCTIC TERN

Cause of Migration.—And do you wonder why birds migrate?

We think that it is the shortage of food that sends them southward in the fall. The insect-eating birds go first, as we should expect, since it is their food that is first killed at the approach of winter. The seed-eating birds stay until later, and even into the winter if the weed stems do not become covered with snow.

But we have no certain explanation of why the birds come back to us in the spring. It is one of the wonders of the bird world that we do not yet understand.

Pathfinding in Migration.—How these creatures find their ways in migration is also much of a mystery to us. A bird may travel thousands of miles in a more or less direct flight. Only rarely do the old birds go first in the fall migration, so they cannot be the guides to the young ones. The flight is often high and usually in the dark, so landmarks cannot serve very much. We are inclined to believe the bird must have some sort of sense of direction. Although no one has located such sense organs, it has been shown that birds taken in covered cages to places a thousand miles beyond their normal ranges are able to find their ways home over routes which must have been totally unknown to them.

Migration, and indeed all of the other things that birds do, must be regarded as mostly mechanical behavior and largely instinctive; or as due to memory intelligence. In no instance is there evidence that birds ever show reasoning intelligence.

But however we explain these things, the birds are mighty interesting things to observe. They do much to make this a pretty world in which to live.

SUMMARY

1. You may spend some delightful hours studying the bird world. Birds are best observed in the hour before dawn, although some are to be found at all other hours of the day.

2. Stalk the bird by walking slowly and *evenly;* avoid frightening it. Note its size (compared with a robin or English sparrow), the shape of its bill, and the color markings (especially on the breast). Obtain some bird book which will help you learn the names of the species you see.

3. Birds are easily attracted to our own homes. Keep a supply of water and food for them during severe weather. Shrubbery, especially kinds that bear berries, will do much to get them to nest about your home. Some species can be persuaded to nest in boxes set out for them.

4. Bird-banding is a new method of bird study that is giving us much information about the ways of individual birds. Only adults are granted permits to engage in such work, but younger folks may find opportunity to help.

5. Birds are found in every type of habitat, especially if water is near by. Each kind of bird is usually confined to a single kind of habitat where its foods are to be obtained.

6. The greater part of the activities of a bird are concerned with food gathering. Most birds are special feeders; some are general feeders. The nature of the bird's wing, tail, bill, and feet determine the food it can obtain (and consequently the habitat in which it will search for that food).

7. Birds fly primarily to obtain food. Only a few birds are poor fliers. The shape of the wing has much to do with the character of the flight. Each species may be identified by its peculiar flight. Young birds do not need to be taught how to use their wings.

8. Each species of bird has a distinctive type of song. A few of them have more than one type. In addition, each species may have one or more call notes which express its emotions. While all individuals of a species have songs typical of the species, no two individuals sing exactly alike, and one may learn to identify the individual birds in any neighborhood by their distinctive songs. The structure of the bird's throat, and its ability to imitate its fellows, determines the sort of song the bird sings.

9. Birds are up before dawn, feeding actively at sunrise, fairly quiet most of the day, active at sunset, and to bed by dusk. Most birds stay within a hundred yards of their nesting sites during all but the migration season. During rainy weather most of them are quiet and cheerless, huddled under whatever shelter affords. Once in the spring and once late in the summer each bird molts and grows a new coat of feathers.

10. The male birds return first in the spring. After the females arrive, they mate, and both males and females engage in the building of the nest and the incubating of the eggs. Each uses particular sorts of material for its nest, usually employing a lining of a finer sort. The form of the nest and its location is also distinctive for each species.

11. Most of our birds migrate from their summer homes to winter homes farther south, some of them travelling tens of thousands of miles each year. The shortage of food in the winter in the north may explain why they go south, but we have no good explanation for their return in the spring. How they find their way in the long migrations is still a mystery. We even believe they must possess some peculiar sense, a still un-located sense of direction.

12. Most of the things that birds do must be regarded as mechanical behavior, or as the result of well-developed memory. Nevertheless, they are unusually interesting things to observe.

DEFINE

Bird-banding
Soaring
Molting (bird)

Migration
Call note

PROBLEMS

1. Make a list of all the birds named in this chapter. How many of them occur in your neighborhood? How many can you identify?

2. What is the most interesting thing you have actually observed in bird behavior?

3. What were the two or three things that interested you most when you read this chapter?

4. Have you ever observed any behavior that indicated that a bird can remember things? Describe it.

5. Have you ever observed any behavior in which the bird showed great lack of reasoning intelligence? Describe it.

6. What birds do you know that stay in your region the whole year and do not migrate?

7. Do you know any birds that migrate into your region in the winter, and leave you to go north in the summer?

8. How many kinds of birds' nests can you identify? What is the distinctive form, material, and location of each?

9. Where, in your own locality, are two or three good places to observe birds?

10. What bird book is the best you know for use in studying birds?

11. What have you observed birds doing in rain storms?

12. Make a list of all the materials you have seen or heard of as being used in bird nests.

13. Give the differences between the male and female birds of three or four species that you may know.

14. In what important respects does the behavior of the domesticated hen differ from the behavior of wild birds?

15. List some of the things in bird behavior that are inherited, and little, if at all, modified by environment.

16. List some things in bird behavior that depend very largely on the individual's experience or environment.

17. Name birds of your region which are extending or have recently extended their range.

18. Name some birds that have materially changed their behavior since white man arrived on this continent.

19. In the above problem, is the changed behavior instinctive or intelligent? Discuss.

20. List some birds that find the conditions of human civilization better for them than conditions in the wild.

21. Name some birds that cannot get along under conditions of human civilization.

BEHAVIOR: REVIEW

1. Review the definitions of all words listed at the ends of Chapters XXXVIII through XLV.

2. Review all of the summaries at the ends of those same chapters.

3. Review the problems given at the ends of those chapters.

4. Explain what is meant by each of the following statements. These are the important principles in that part of Behavior which you have studied.

CHAPTER XXXVIII. **Reflexes and Tropisms.**—In the science of Behavior we have two problems: What do living organisms do, and why do they do it?

Reflexes and tropisms are mechanical responses of organisms to definite stimuli. The organism has to react to such stimuli much as a machine would have to act.

CHAPTER XXXIX. **Instincts.**—Chains of inherited mechanical responses (*i.e.*, of reflexes and tropisms) are called instincts. Much instinctive behavior is adaptive. It may be modified by reason or by other factors.

CHAPTER LX. **Intelligent Behavior.**—Behavior is intelligent if it shows that an organism has profited by its experience. Intelligence is not inherited, although the ability to be intelligent may be.

Memory of past experiences is the simplest type of intelligence. It is well developed among many insects and in birds, as well as among the mammals.

Reasoning is a process of choosing which of several stimuli (often memories of past experience) may be allowed to control present behavior. (Recall what we do at a cross-roads!) True reasoning is found only among a few insects and in several of the mammals.

Man is most different from other animals in his highly developed ability to reason.

Habit is any type of behavior which has become more mechanical through repetition.

CHAPTER XLI. **Social Wasps and Bees.**—Social animals care for their young and live with other adults with whom they divide the colony labors and share a common food supply.

Besides the human, social wasps, social bees, the ants, and the termites are the only truly social animals. These other animals face many of the same problems of social organization which we face.

Chapter XLII. **Ants and Termites.**—The observation of these insects may provide endless entertainment for the person who will take time to look at them.

All of the behavior of these remarkable insects may be explained as reflex, tropism, instinct, or memory behavior.

Chapter XLIII. **Parasitism.**—A parasite secures its food supply from its host, without killing that host immediately, if at all. Parasitism is delayed predatism. The behavior of the parasite must be highly specialized so it will fit into the life of the host.

Chapter XLIV. **Solitary Wasps and Bees.**—These are the most remarkable of insects in their behavior. One may observe endlessly different types of behavior among the thousands of different wasps and bees of this group.

These insects show chiefly instinct and memory in their behavior, but a few cases of reasoning—the only cases known in the insect world—occur in this group.

Chapter XLV. **Bird Behavior.**—Birds are among the most delightful of the interesting things in this world, although none of their behavior seems to involve reasoning.

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CONCLUSION

CHAPTER XLVI

HISTORY OF BIOLOGY

In this day of many books and teachers, it is difficult for us to understand how there ever could have been a time when men were ignorant of easily observed facts of biology. But our present knowledge has been gained only after long centuries of effort, and there is a lesson for us to get from the story of how men made our science.

The Beginnings

Of course, from the very beginning man must have observed plants and animals, for they were all about him, and he himself was an animal. Such things as could be eaten, plants that could be burned in fires, wood and bones that could be made into tools, fur animals that furnished clothing, the creatures that were deadly enemies, the lice, fleas, and other pests that bothered him, and the dogs, horses, cattle, and other animals that would serve him must have been, beyond his own species, the first organisms that primitive man noticed. Biology originated as a body of practical knowledge. At least we presume so, although we have few definite records of the first million years of human history.

We may obtain some idea of the beginnings of our science by noting the information which primitive and back-woods people have today. Our American Indians knew thousands of species of plants, the habitats in which each kind grew, which were good

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FIG. 481.—ARTISTS OF THE OLD STONE AGE

Recording man's early interest in biology. The mammoths, cut and painted on the walls of this cave in Western France, have long since been extinct.

for food, which were poisonous, which gave dye materials, which had medicinal values in their seeds, leaves, or roots. The native knowledge must have been based upon accurate observations and a considerable amount of experience, experiment. The precision of their knowledge has called forth the admiration of our trained taxonomists. Primitive peoples all over the world have held similar acquaintance with plants and animals, and although their observed knowledge was often confused with gross superstition, our biologic science had its beginnings in that sort of thing.

By the time men began to make written records of their affairs, a few thousand years before the Christian era, some clever observations had been made. In the days of Moses, for instance, there were Egyptians who knew that adult, winged blowflies develop from maggots that live in decaying stuffs, and that frogs grow from tadpoles.

From Locy Biology and Its Makers. Courtesy Henry Holt &

FIG. 482.—ARISTOTLE, 384-322 B.C.

Aristotle

Formal biology started with the brilliant work of the Greek philosopher and observer, Aristotle.

His Life.—Born in 384 B.C., the boy and the man were favored by fortune and he was offered rare chances for the study of plants and animals. His father was a physician, and the young Aristotle, after the death of his father, was taught in the school of the physicians. There he acquired such knowledge of animal structure as was had in that day. Then he went to study at Athens.

Trained at Athens, under the teachings of the philosopher Plato, Aristotle finally rebelled against his teacher's method of trying to discover things by theorizing about them. So he left Plato and set to using his own method of observing things directly, basing his opinions on such well-established data. It was a very simple method, you see, but one which few men before that day had so consistently followed, and the very one on which we still depend in science. It is remarkable that in a definite time and place a single man should have founded not only a science, biology, but the method upon which the other sciences are based.

About this time Philip, king of Macedonia, chose Aristotle as the tutor for his son Alexander, later known as Alexander the Great. Aristotle taught the young Alexander mathematics, grammar, public speaking, debating, civics, history, and biology. This was almost as much as any learned man knew in that day. In return Alexander gave Aristotle great wealth, and the teacher's fame became widespread. When he returned to Athens, Aristotle opened a school which he called the Lyceum, and there he lectured each day to learned men and beginning students. It was with the help of these many students that Aristotle produced, in twelve short years, the many scientific and other studies which he left us.

His Work.—Aristotle's biologic observations were recorded in a number of books which equalled in all two or three modern volumes. Parts of these books were written by some of Aristotle's students, the accounts of plants being chiefly the work of Theophrastus.

Some day you should read an English translation of some of Aristotle's biologic work. You will be surprised to find what he learned. He knew, for instance, that the drones in a honeybee hive come from eggs that have never been fertilized. He had observed the growth of embryo chicks in their shells, and he knew that each organ develops only gradually, just as you learned in the chapter on embryology. He knew of the extremely complicated mating behavior of the squid, one of the peculiar molluscs of the ocean; and so remarkable were these observations that they were considered mere fancy after Aristotle's day, until in 1851 they were again verified.

In the same century in which Aristotle lived, Athens was the home of Demosthenes, the famous orator and statesman, of Praxiteles, the great sculptor, and of Socrates and Plato, the philosophers. But of all these great men, Aristotle was probably the most brilliant. His philosophy still ranks as one of the best ever developed; his writings on governments furnish the foundation for our modern political science (civics); his logic (the rules for reasoning about things) has been little improved since his day; and we are proud to acknowledge Aristotle's observations and the scientific method which he developed as the real beginning of biologic science.

The Middle Ages

With this start, why shouldn't knowledge have steadily improved? Instead, it almost immediately began to decline. Greece was conquered by Rome, and her concern with scientific things gradually diminished.

Pliny, a Roman living about 50 A.D., attempted to gather all of the scattered knowledge of biology, but he did not know how to distinguish proved facts from hearsay, and his work was a peculiar mixture of science and superstition. While he praised experimentation, he failed to employ it himself when he accepted the notion, for instance, that an egg shell couldn't be broken unless it were tipped to one side. By standing an egg upright, and using a stone of sufficient size he might easily have proved the contrary.

Then the Roman Empire was conquered by barbarians from the North, and things seemed dark indeed. The barbarians in time became eager enough to learn, but they had to start at the very bottom. Fortunately the Church became an agency which preserved and passed on some of the intellectual attainments of the past, but it was natural that it should be more interested in religion, and biology was largely neglected.

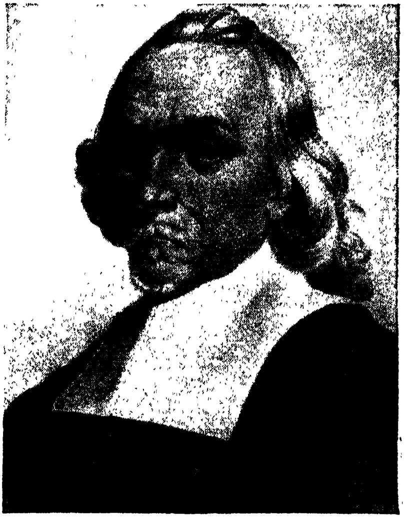
Ignoring the world in which they lived, men were much concerned about their future lives. The authorities tried to establish what should and should not be believed. Venturesome folks who attempted to obtain their knowledge from direct observations of nature were charged with meddling in the Creator's secrets, and if they disagreed too seriously with the accepted opinions they were likely to be put to death. When spectacles, microscopes, and telescopes were first invented some people objected that the Creator would have given such things to men in the beginning if he had intended them to be used. In regard to spectacles it was further argued that one who saw poorly with his own eyes would see twice as poorly if he placed glasses before his eyes, and so the use of lenses of all kinds was forbidden.

Science could hardly thrive under such conditions. Scientific progress depends upon the opportunity to make free, unhampered inquiries. People did not try to observe the facts about things. As an extreme instance of the peculiar methods often employed, we hear of monks who engaged in endless debates as to how many teeth a horse had. All the approved authorities were quoted on the subject, but no one had wits enough to make direct observations of a horse's mouth!

There were, of course, men in those times who had native, hereditary qualifications for becoming scientists. Some of them, as Roger Bacon, living in the thirteenth century, made real contributions to science and helped introduce the spirit of experimentation. But the practical application of their suggestions was slow to be made. In the thousand years of the Middle Ages, the total advance in biology did not equal what Aristotle had learned in a single lifetime of simple observation, or what modern science now discovers in a ten-year period.

Experimental Science

No single hero, no great event, brought the world into the second great age of science. A thousand things worked to accomplish it. The Church reformed its attitude, cities were established and men met new problems in them, the Americas were discovered, Magellan's expedition sailed around the world. Our planet was proved round. The denial of observed fact became harder, bold spirits were encouraged to forsake old authorities for the exploration of new fields, and the invention of the printing-press offered knowledge to the masses who had hitherto lived in ignorance. This was the atmosphere in which the biologic sciences found their revival.



Courtesy Col. F. H. Garrison and Army Medical Mus.

FIG. 483.—WILLIAM HARVEY, 1578-1667

Harvey and the Circulation of Blood.—Among the earlier discoveries of this period, the circulation of the blood was announced by William Harvey, an Englishman, in a book published in 1628, just about the time the Pilgrims were landing on the New England coast. It had previously been held that a mammal's blood washed back and forth in the fashion of an ocean wave within the veins and arteries. It was a difficult matter to observe directly. Few of us today have ever seen the circulation of the blood. Harvey had to employ numerous clever experiments to prove his point. This was the first important use of experiments in the history of biology, but since then the method has proved remarkably profitable.

The Microscope.—The invention of the microscope just before 1600 was another important event in biology. The early instruments were strange things compared with our modern tools, but they did magnify, and they allowed the human eye to see organisms and structures whose existence had not been imagined before. Microscopic algæ and fungi, bacteria and protozoa, the cells of which all plants and animals were found to be built, a knowledge of early embryonic development, the morphology of the smaller organisms, the existence of chromosomes and of their behavior in heredity, and many other as important things are the direct results of the invention of magnifying lenses and their improvement in the last century.

Courtesy Amer. Mus. Nat. Hist.

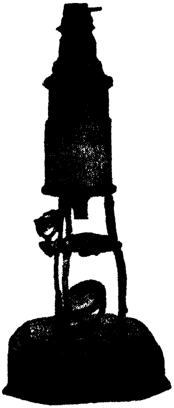
FIG. 484.—CHARLES DARWIN (1809-1882)

English biologist, student of island life, barnacles, domesticated plants and animals, natural selection, earthworm behavior, pollination of flowers, and plant movements.

Modern Biology

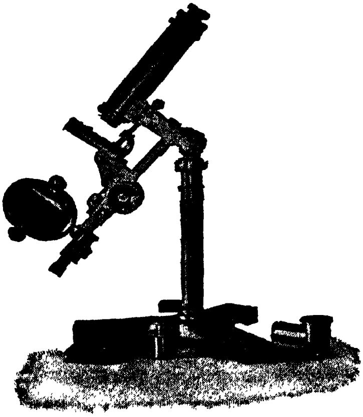
Science prospered between 1600 and 1860. A long list of names of great biologists of that period might be given. Some of them, Redi, Linnæus, and Lamarck, have been mentioned elsewhere in this book. All of our modern knowledge of taxonomy, morphology, physiology, ecology, and behavior was being established. It is difficult for us to realize how much work was being done in that period in order to discover the facts that we now learn so easily from our textbooks.

Darwin.—Modern biology, however, may be dated from a single event. That was the publication in 1859 (just before



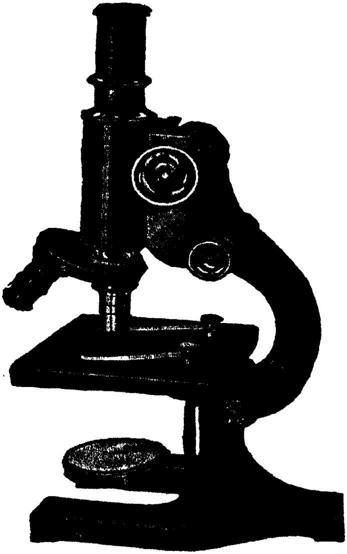
Courtesy Amer. Mus. Nat. Hist.

FIG. 485. — THE MICROSCOPE: FROM THE 1700'S



Courtesy Spencer Lens Co.

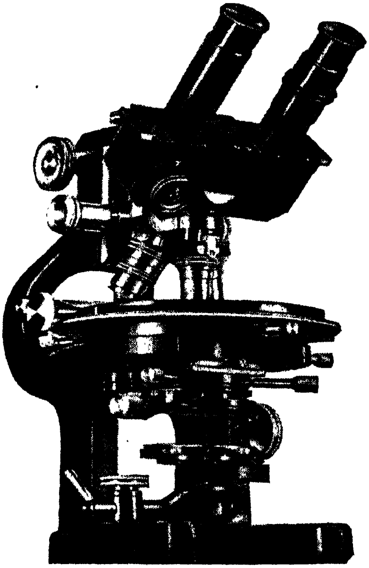
FIG. 486.—THE MICROSCOPE: 1850



Courtesy Spencer Lens Co.

FIG. 487.—A MODERN MICROSCOPE

For general use.



Courtesy Bausch & Lomb Optical Co.

FIG. 488.—A RESEARCH MICROSCOPE

Equipped for high-power work.

EVOLUTION OF THE MICROSCOPE

our Civil War) of Darwin's work on evolution. Although numerous biologists had previously said that species change, it remained for Charles Darwin to offer such abundant proofs that the whole scientific world was attracted and convinced of the truth of the idea. Since then modern biology has kept evolutionary notions to the fore. It has reclassified the plants and animals and arranged them to show their origins from common ancestors. It has studied living structures with the idea of making comparisons and showing how similar structures may have originated. It has built up the science of genetics, which aims to discover why individuals are so similar and why they sometimes vary and give rise to new species.

Huxley.—In these seventy-five years there have been many brilliant biologists. Huxley, another Englishman (who died in 1895), was an observer, public speaker, and teacher who did much to make science intelligible to the average man. He it was who introduced laboratory work into the elementary science courses given in high schools and universities.

Pasteur (who also died in 1895) was a French biologist whose work on bacteria we have already described (Chapter XXII).

Robert Koch (died 1910), the German bacteriologist, worked in the same period as Pasteur, and with Pasteur shared the honor of founding our modern knowledge of bacteria and of the control of germ diseases.

We have also learned (Chapter XXV) how our knowledge of heredity was founded by the work of the Austrian monk, **Gregor Mendel** (died 1884).

Von Baer, a German (died 1876), established our modern science of embryology.

Weismann, a German (died 1914), and **de Vries**, a Dutchman (still living), taught us much about evolution and heredity.

Wallace, an Englishman (died 1913), also dealt with problems of evolution, and founded our knowledge of distributional biology.

Henri Fabre, a Frenchman (died 1915), made patient observations on the lives and behavior of insects. Many of the stories to be found in our section on Behavior were first told by this French entomologist. His volumes were written in such an interesting way that, I am sure, you would enjoy reading them.

Schleiden (died 1881) and **Schwann** (1882) were the two German botanists who developed our knowledge of cells as the basis of all plant and animal structures.

Sachs (died 1897), another brilliant German, contributed to our understanding of photosynthesis, respiration, water relations, and other aspects of plant physiology.

These are only a few of the many great names that have contributed to our modern biology. In the portraits in this book, still other biologists are listed.

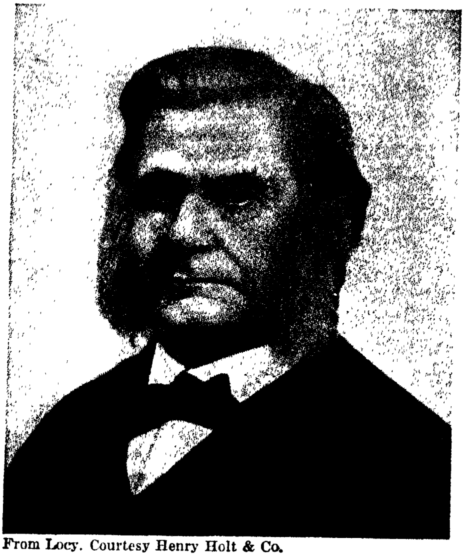

From Locy. Courtesy Henry Holt & Co.

FIG. 489.—THOMAS HENRY HUXLEY, 1825-1895

American Biology

In America there was little attention paid to natural sciences before the middle of the past century. In the last half of the century Americans here and there began to turn their attention to biology. Today there are several thousand professional biologists in this country, and innumerable others who are deeply interested in the study of plants and animals.

This great development of our science is a recent thing, and it is difficult to pick out names of Americans who in time will be ranked with the great biologists of history. But this is because we now have scores of outstandingly great scientists for every one that lived a century ago. With so many at work it is difficult for any one of us to become so well acquainted with the great leaders as we might have done in the past. But do not think that there are no great discoveries being made today. The great army of workers, the great advantage we have of starting where our predecessors left off, and the wonderful equipment that modern wealth and modern inventions put at our disposal—all of these mean that the amount of really important discovery made each year is greater than ever before. Perhaps half of our biology book has been concerned with things that have been discovered in the last third of a century by investigators in our own country. The following list of a dozen names will give some idea of the different fields in which Americans have been and are leaders.

E. V. McCollum (1879-).—Biochemist (studying the chemical basis of biologic phenomena). A brilliant student of nutrition, particularly of vitamins and balanced diets. In the School of Hygiene at Johns Hopkins University, Baltimore. See Fig. 490.

E. B. Wilson (1856-).—Cytologist. Student of cell structure and function. One of the first to follow single cells and their later history in embryonic development. To be credited with much of the work in identifying chromosomes as the carriers of heredity. See Fig. 491.

T. H. Morgan (1866-).—Experimental embryologist and geneticist. His first work in the experimental study of the factors which determine the course of events in embryonic growth. With the rediscovery of Mendel's Laws in 1900, Morgan became a leader in studying the relations of chromosomes and genes to heredity. For many years at Columbia University, now at the California Institute of Technology. Recently granted

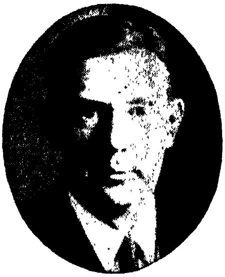


FIG. 490
E. V. McCOLLUM

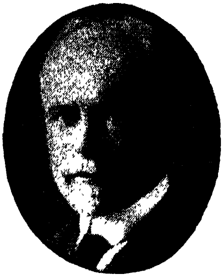


FIG. 491
E. B. WILSON

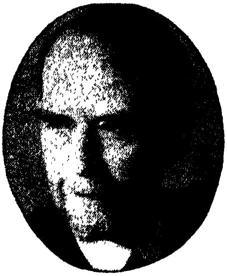


FIG. 492
T. H. MORGAN

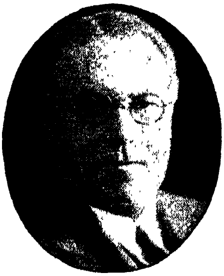


FIG. 493
W. B. CANNON

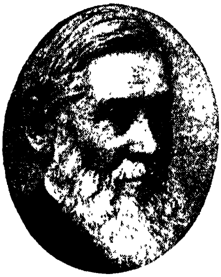


FIG. 494
ASA GRAY

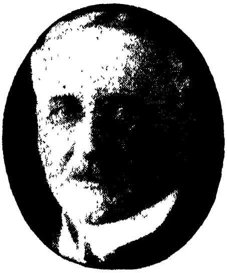


FIG. 495
JACQUES LOEB

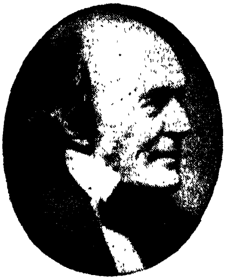


FIG. 496
LOUIS AGASSIZ

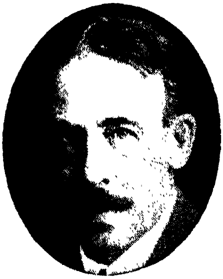


FIG. 497
W. M. WHEELER

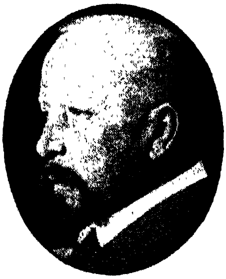


FIG. 498
L. O. HOWARD

A GROUP OF AMERICAN BIOLOGISTS

a Nobel Prize because of the importance of his work on heredity. See Fig. 492.

W. B. Cannon (1871-).—Physiologist, studying digestion; the physiologic changes that are the causes of such emotions as hunger, fear, anger, etc.; and the physiologic changes that result from "shock." Located in the Medical School at Harvard University, he is a leader in recognizing the importance of a broadly biologic training for medical students, and in his insistence that medical practice be based on sound, scientific research. See Fig. 493.

Asa Gray (1810-1888).—Taxonomist, a pioneer student of American plants and their distribution. Was on the faculty at Harvard University. Explored widely over this continent in a day when such travel was difficult and unusual. Often known as the "Father of American Botany," chiefly because of the importance of his manual for the identification of plants. The section on plant morphology in "Gray's Manual" was widely used in teaching botany. See Fig. 494.

Jacques Loeb (1859-1924).—A remarkably brilliant physiologist. Particularly responsible for the great development of physiology at the beginning of the present century. Did special work on a variety of subjects, including sense reactions, tropisms, animal behavior in general, the chemical and physical processes involved in fertilization, and the composition and physiologic nature of protoplasm. One of the first to believe that all biologic processes depend upon the structure and the chemistry of plant and animal tissues. This idea of the "physico-chemical basis of life" is now accepted as one of the most important in biology. Was on the research staff of the Rockefeller Institute. See Fig. 495.

Louis Agassiz (1807-1873).—Naturalist and taxonomist. Born a Swiss, migrating to America as a young man, for the rest of his life a leader of the biologists at Harvard University. Having been well acquainted with glaciers in Switzerland, he was able to recognize that glaciers had formerly covered much of the northeastern portion of North America. Was practically the first to study the relations of the Great Ice Age to plant and animal distribution. Also a student of fish, for which his explorations extended to South America. Even more noted as a great teacher. Introduced laboratory work in beginning courses at Harvard; but always insistent that students "study nature, not books." See Fig. 496.

W. M. Wheeler (1865-1937).—Entomologist, student of insect behavior, particularly that of ants and of the other social insects. His scholarly volumes on ants, ant-lions, solitary wasps, etc., are among the most important reference books on behavior. Also a student of insect embryology. At one time at the University of Texas, then for many years at Harvard University. See Fig. 497.

L. O. Howard (1857-).—Economic entomologist, one of the first American students of that subject, and responsible more than any other man for the fact that Americans have led the world in developing methods of insect control. Always insisted that we must learn the taxonomy, morphology, physiology, and behavior of an insect before we may expect to control it. Encouraged some of the first work on the relations of insects to disease. Particularly interested in biologic control as the best way of controlling insect pests. Honored by several foreign governments for his furtherance of international cooperation in the prevention of insect spread and in other problems of world-wide importance. For 33 years was chief of the U. S. Bureau of Entomology located at Washington, D. C. See Fig. 498.

Applied Biology.—American biologists have always been particularly interested in making practical applications of their studies. Agriculture has been greatly benefited by studies of plant physiology, genetics, ecologic balance, and pest control. Medicine, once based on practical experience with a considerable dose of superstition in it, is becoming an applied science, utilizing both biology and chemistry in its attempt to further health and control disease. Public health and sanitation, ornithology, and forestry have been especially advanced in this country, and economic entomology, concerned with the control of insect pests, is primarily an American science (see notes under L. O. Howard, above).

Unexplored Fields

But in spite of all of this activity, we have hardly begun to touch the things there are to be investigated. The more we learn, the more we realize that we know very little about living organisms. Anyone, boy or girl, trained scientist or beginner, who will make careful observations on plants and animals, on even the commonest, may be certain of finding things that no man has previously discovered.

FIG. 499.—EXPLORERS

For those who will look, there are still worlds of interesting facts to discover.

The way in which a grasshopper breathes was discovered only a few years ago by a young man whose experiments could be repeated by a good high-school student. How long it takes the common cockroach to grow into an adult was unknown until a short time ago. The way in which a spider gets a thread from one tree top to the next one is still, I think, not understood. The way in which the male helps the female mud-dauber wasp (the species that builds the common organ-pipe nests) has been observed by perhaps not ten people, and still needs much investigation. The life history of such a common species as the house centipede is, as yet, unknown. The activities of the chiggers, in between the times when they are pestering humans, are not well understood.

Why the common newt (a salamander of the eastern United States) is sometimes olive green and sometimes red in color is not satisfactorily explained. Where insects sleep at night, how birds sleep, and how many plants show "sleep" movements are still largely mysteries that will present no great difficulties in the solving. You must help us investigate some of these things!

Bit by bit, at much cost, our knowledge of biology has been built. Men have been slow to learn what an interesting world we live in. But with the treasury of information which our predecessors have bequeathed us we may go far ahead in learning about plants and animals.

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SUMMARY

1. Our present knowledge of biology has been gained only after long centuries of patient observation of plants and animals.

2. Biology originated as a body of practical knowledge. Primitive peoples had extensive knowledge of the organisms with which they came into direct contact, especially if those plants or animals were useful to them.

3. Formal biology started with the Greek philosopher, Aristotle (born 384 B.C.). He based his knowledge on his own direct observations, thus establishing the method which we now use in science. His biologic contributions show great ability and surprising accuracy in observation.

4. Pliny, a Roman living about 50 A.D., wrote a natural history that was a peculiar mixture of science and superstition.

5. During the first fifteen centuries of the Christian Era, the total contribution to science was very little. The authorities tried to establish what should and should not be believed, and instead of depending upon direct observation, people obtained their knowledge from books which were often filled with strange superstitions and inaccuracies.

6. The use of direct observation and experiment as a means of obtaining knowledge began to be used more extensively during the early 1600's. William Harvey's discovery of the circulation of the blood was one of the first important uses of experiment in biology.

7. The invention of the microscope just before 1600 gave biologists the instrument that has been of more use than any other in the investigation of plant and animal structures.

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* Recommended as the best volume for a high-school reference library.

8. Modern biology dates from 1859. Darwin's work on evolution, published in that year, convinced biologists that in all of their work they must remember that no two individuals are alike, and that new types of individuals give rise to new species.

9. Redi, Linnæus, Lamarck, Huxley, Pasteur, Koch, Mendel, von Baer, Weismann, de Vries, Wallace, Schleiden, Schwann, Sachs, and Fabre are names of biologists with whose work you should be acquainted.

10. American biology dates from the middle of the past century. Since 1900 so many American biologists have made outstanding contributions that it is difficult in a short history to name the particular men who have contributed. Americans have given particular attention to applied sciences like agriculture, public health and sanitation, forestry, economic entomology, etc.

11. Bit by bit, at much cost, our knowledge of biology has been built. But we have only begun to explore the living world about us. There are endless opportunities for accurate observers to contribute new facts to our

IDENTIFY

Aristotle
Theophrastus
Middle Ages
Pliny
Harvey
Leeuwenhoek
Redi
Linnæus
Darwin
Schleiden
Schwann
Huxley
Pasteur
Mendel
von Baer
Weismann
de Vries
Wallace
Fabre
Koch
Sachs
E. V. McCollum
E. B. Wilson
T. H. Morgan
W. B. Cannon
Asa Gray
Jacques Loeb
Agassiz
W. M. Wheeler
L. O. Howard

PROBLEMS

1. What experience have you ever had, or what stories have you heard, which might indicate that uneducated people have accurate information concerning plants and animals?

2. Make a list of all the scientists whose portraits are shown anywhere in this book. What was the chief contribution of each to biologic science?

3. How many different countries are represented in the above list of scientists?

4. How often are the different units of our biology course (seven of them), represented in this list of scientists?

5. How many of your list of scientists were interested in pure science? How many in practical applications of biology? What does this fact mean?

6. Why have Americans, more than any others, been interested in making practical applications of their science? There are several reasons for this. Carefully consider your reply.

7. If you were a scientist, would you rather have lived in some past period of history, or would you prefer to be living today? Why?

8. Why is it that historians now prefer to call the period the Middle Ages, instead of the "Dark Ages," as it was formerly designated?

9. Harvey's discovery of the circulation of the blood has been called one of the three or four greatest events in the history of biology. Hundreds of discoveries have had more practical applications. Why was Harvey's discovery so important.

10. Indeed, how could *you* prove that the blood circulated in your own body? You can prove that it moves, but how can you prove that it *circulates?*

11. What are the two or three most important lessons that we, of today, may learn from the history of biologic science?

12. What proportion of the facts about the common plants and animals of your state do you think are still undiscovered? Make a guess. Compare with the guesses of the others in your class.

13. In certain fields of biology, the development of the automobile has been almost as important as the development of the microscope. Explain.

14. Select one or more of the biologists named in this chapter. From other references, find out more about him than is given in this book, and make a short report to the class.

15. Why were the early botanists so often interested in plants useful for medicine, and not so interested in plants useful for food?

16. What plants can you name which are still used in modern medicine?

CHAPTER XLVII

SCIENTIFIC METHOD

The two most important things which we have learned from our biology course are these:

That it is an interesting world in which we live.

That the scientific method is a good one to follow in our everyday lives.

Throughout our study we have been learning what a store of interesting things may be discovered among the plants and animals which are about us.

Also throughout our course we have been trying to persuade each of you to learn things in a strictly scientific way.

Now let us make a definite statement as to what it means "to be scientific."

Observation

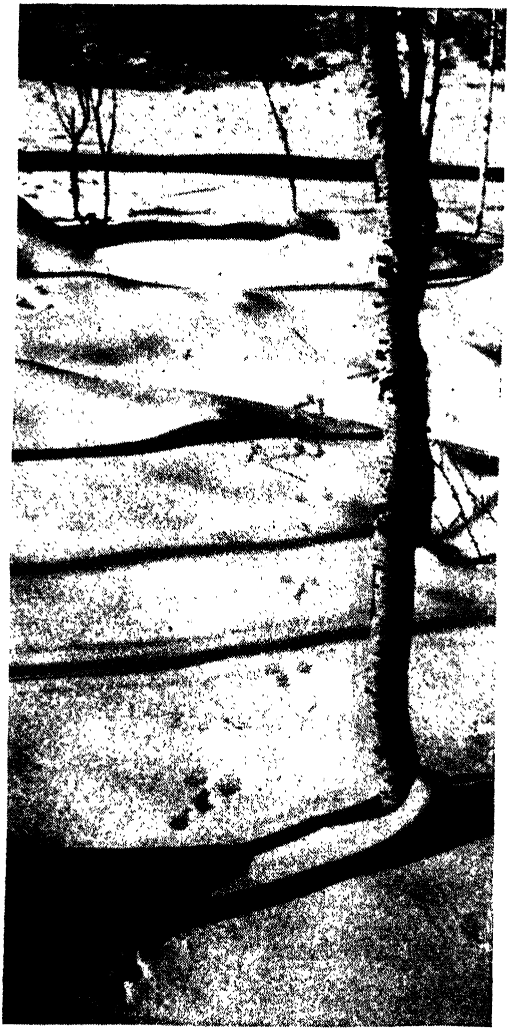
We speak of this as a "scientific age," and we attach great importance to doing things in a scientific fashion. Advertisers have learned that they can sell things if they are labelled as the result of scientific research. The public has great respect for the contributions which science has made to our modern civilization—but I fear that few people could tell what it means to be scientific.

There is a mistaken notion that science is a study of big words and high-sounding phrases, that a science laboratory is a maze of expensive apparatus for performing ingenious experiments, and that the scientist is a peculiar individual so far removed from everyday ways that he is to be admired but not imitated by normal men. As a matter of fact, the scientific method is the oldest, the best-known, and by far the simplest of all methods of discovering facts in this world.

Knowledge Obtained through the Senses.—When a scientist wishes to learn things, he uses his eyes, his ears, his nose, his sense of touch, or his other sense organs to *observe* them. He *looks* at things, or he *touches* them, or *tastes* them, or *listens* to them. He does what the average child would do if it wanted to learn about that same thing.

That is the first and most important thing in the scientific method.

It is, you see, the most natural method in the world. Johnny Jones was born with a considerable disposition to use that method in his own



Courtesy Dr. A. R. Cahn and Nature Magazine

FIG. 500.—A TEST IN OBSERVATION

You have probably seen rabbits jumping. Which way was this rabbit going? Are the two rounded marks which are side by side prints of the front or of the hind feet of the rabbit?

education. He first learned about stone walls when he ran into one, one day. He learned about many other things by grasping them, by tasting them, and by looking at and through them, as babies and small children and scientists always do.

Authority and Observation.—At first thought, you may not realize that there are other ways of determining the qualities of stone walls. But there are ways which many people prefer to use. It is so much easier to ask somebody else whether the wall is there. And it is quite possible that there is some book on the subject or a map that will save you all of the trouble of going to the field to determine the matter. Such indirect sources of information are called *authority*.

Many people have so much respect for authority that they are inclined to believe whatever they hear or whatever they see in print even if it is contrary to the evidence of their own eyes. A scientist, on the contrary, considers authority a second-hand sort of information which may be inaccurate or completely contrary to the actual facts.

It is true that we have to depend upon other people's word for obtaining some of our knowledge. Many of the facts of biology, for instance, have been learned only through the work of hundreds of observers scattered in any number of different places in the world, and it would be impossible for each of us to observe directly all of these things.

But then we need be very careful to distinguish good and bad authorities.

Few men have information on more than a few subjects. One may be a good authority in biology and a very poor one in chemistry. Indeed, a man can be an expert on only a few of the many parts of biology, and that is why it was necessary to have a long list of specialists go over the various chapters in this book.

It should hardly be necessary to advise you to go to biologists rather than to others who perhaps are not even scientists to find out the facts of biology.

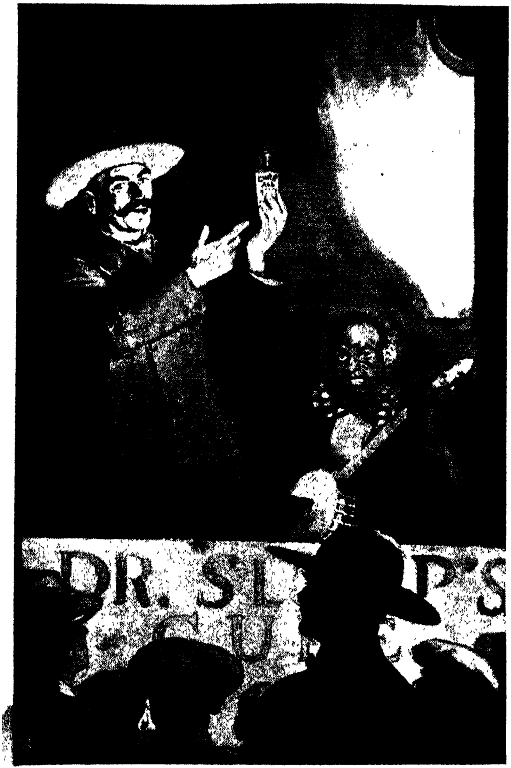
A printed statement cannot be a better source of information than the man who wrote it. Find out who wrote what you are reading and inquire if he is a properly qualified authority on the subject.

Beware of such unsigned articles as sometimes appear in newspapers and magazines. You cannot tell whether the statements are well established if you don't know the author.

Again, remember, that even authorities sometimes publish things that are not so. They are human, and make mistakes occasionally. It even happens that what experts believe to be true may be found incorrect upon further investigation. We frequently have to change our opinions of things in the sciences.

Reason and Observation.—Another substitute commonly employed in place of direct observation is reason, or *philosophy,* as we often call the extensive use of reason. While we have emphasized the fact that the human animal differs from all others chiefly in its ability to reason, scientists consider reason a poor substitute for direct observation. There are some things which cannot be observed. Spirits and supernatural things, and such structures as are too minute for our microscopes to show us or too distant for our telescopes to fathom, can be known only through reasoning about them. We then have to reason out, to "figure out," as the average man would say, how such unobservable parts of the world *should* look if we were able to observe them.

But many people like to reason out things that might very well be determined by direct observation. I suspect that that is because it is so much easier and more comfortable to sit in an armchair in front of a comfortable fire—to sit and reason instead of going and observing how the world is actually made. Medieval monks were not the only ones who debated the number of teeth in a horse's head without ever looking into the animal's mouth to count them. It is in the same fashion that we find people today who believe that rusty nails driven into tree trunks will make the trees stronger, that tobacco juice on worms makes them better for fishing, that horsehairs can turn into snakes, that hoop snakes can swallow their tails and roll down hill like wagon wheels, that it is dangerous to eat lobster with milk, that one may contract warts by handling toads, that bad air causes malaria, that four-leaf clovers bring good luck, that it is desirable to wait for a good moon before planting crops, that cutting cats' tails will cause them to have bob-tailed kittens, or that any of a hundred other such superstitions have some truth to them.



Courtesy Metropolitan Life Insurance Co.

FIG. 501.—BEWARE OF POOR AUTHORITY!

The patent-medicine fakir insists that the medicine will cure you. "Read the label and see for yourself!" And people are so easily persuaded that a big insurance company has to warn against such arguments.

Most of these conclusions have been reached by reasoning processes which may appear to have some merit in them; but every one of them can be disproved by a few simple observations on the matter. It is, therefore, thoroughly unscientific to believe in them.

Wishful Thinking.—But the most astounding method of learning things consists in deciding how we would *like* to have the world, and then believing it is made that way. We would *like* to believe that all folks are born free and equal, that all things work together for good, that every plant and animal structure has a useful purpose, that the human body is a perfectly designed machine, that the effects of environment may be inherited, that the lives of the birds are models of happiness and proper behavior, that the rest of the world is made as we would *wish* it. Look about you, and see how many people reach conclusions in that fashion. Consider how often you and I have accepted things in exactly that same fashion.

But to be scientific means that one must accept what he sees, hears, tastes, smells, or otherwise observes, whether it is what he would *like* to see, or what he would *like* to hear, or would *like* in any fashion to observe. The artist, the philosopher, the student of religion may properly ask himself whether things are good or bad, beautiful or lacking in beauty, nice or unpleasant, as we would like them or as we do not like them. But for the scientist there is only one question: Are things true —can we observe them?

Respect for Observation.—All men believe more or less of what their senses tell them. A scientist differs from the average man in his supreme respect for observation as a means of obtaining knowledge.

Cause and Effect

But there is one thing more in the scientific method.

After he has observed things as he finds them, the scientist is interested in trying to discover *why* things are as we observe them. We believe that there is some good and sufficient reason, a *cause* for everything that happens.

In a science course it is not sufficient to memorize mere statements about things. We have continually asked that you learn the explanations of things. It is not enough to learn that you should clean your teeth regularly, each day. It is scientific to learn *why* our teeth need that scrubbing. It is not enough to know that there is a three-to-one ratio in heredity, that environmental effects cannot be acquired by one's descendants, that an arthropod grows by a process of molting, that roots grow down and stems grow up, and grass is green, and violets are blue—that many other things are believed to be true. If you haven't learned *why* each of these thousands of things is so, you have failed to learn the scientific method. Scientists, I repeat, believe there is some good and sufficient reason for everything, and it is part of the business of science to discover such reasons.

rtesy N. Y. Zoological Soc.

FIG. 502.—PROVING ANOTHER SUPERSTITION UNFOUNDED

Similarly, in everyday life, we believe that nothing happens by haphazard chance. Success is not an accident. High school credits do not ordinarily come for less than sufficient attention and study. Men's hopes and dreams are realized only after long hours of hard work. Nations cannot secure wealth and leisure without working for them.

As it is sown, so shall it be reaped.

If our work has been good, the reward will be as profitable; perhaps not immediately, and in the form we would have it, in dollars, or high political office, or social importance, but in some way worth all that we have put into it.

This idea of the relation of cause and effect is the second fundamental of science.

Courtesy R. B. Rockwell, Denver

FIG. 503.—GROUND-SQUIRREL AT ITS HOLE

The scientific method is, you see, a very practical thing that may be applied to the affairs of our everyday lives as well as to biology and the other sciences.

SUMMARY

1. The most important thing which we have learned from our biology course is this: That it is an interesting world in which we live.

2. We have also learned that the scientific method is a good one to follow in our everyday lives.

3. A scientist obtains knowledge primarily through his sense organs. He *observes* things. This is the simplest and most natural method of obtaining information.

4. While it is necessary to depend upon the observations of other people—*authority*—for some information, scientists are careful to distinguish good from bad authority.

5. Only specialists can be good authorities. A printed statement is no better authority than the man who wrote it. Unsigned articles are not acceptable as authorities.

6. Scientists consider reason a poor substitute for direct observation.

7. Many people do wishful thinking—deciding how they would *like* the world and then believing it is made that way.

8. Scientists reject all these other methods of learning things, considering observation the best of all means of obtaining knowledge.

9. Scientists are also interested in learning *why* the world is as we observe it. They believe that there is a good and sufficient reason (the *cause*) for everything that happens.

10. As it is sown, so shall it be reaped—this is a second fundamental of science.

DEFINE

Science
Scientific
Observation
Authority
Superstition
Wishful thinking
Cause
Effect
Philosophy

PROBLEMS

TEACHING NOTE.—Students are most likely to develop scientific attitudes if the biology course, throughout the year, has placed the emphasis on first-hand observation. Students should be encouraged to make such observations in the laboratory, in the field, and at home. They should be convinced that first-hand observation will enhance the ratings which they receive for recitations, laboratory, notebook work, and examinations

As a means of aiding the student in the formulation of his ideas on scientific method, this chapter has been materially lengthened by the following extensive of Problems. They may well provide subjects for several class discussions.

1. When you have a chance to choose your food, is your choice based on your degree of hunger, on cost, availability, likes and dislikes, or other things? On what should a scientific choice of foods be based?

2. To what extent is your choice of clothing based on scientific considerations, and to what extent on something else? Explain.

3. What instances can you give of truly scientific attitudes being shown by your local, state, or federal government in dealing with some of the important problems they have had to solve in the last few years?

4. Give instances of political views held by you or by your friends which you think were developed in a strictly scientific fashion. Discuss.

5. Is Domestic Science a true science? Be prepared to debate this.

6. Is Political Science (otherwise called *Civics* or *Government*) a true science? Be prepared to debate this.

7. Explain how the Social Sciences could become more scientific in their consideration of some one of the following topics. criminology, law enforcement, juvenile delinquency, unemployment, city or state government, etc.

8. For which of their problems should your town, city, county, or state governments call in biologists for expert advice? Take time to give careful thought to this. You should be able to make a list of some size.

9. List all the courses you have taken in school during the past year. For each give an instance of something which was considered in the course in other than a scientific way. Should that subject have been treated scientifically? Carefully explain.

10. From a purely scientific standpoint, who should choose the textbooks that are used in a high school?

11. What is the difference between a biologist and a person who is merely interested in plants and animals?

12. Name some things that science cannot study, but must leave for the artist, philosopher, or other students to study.

13. What is there about the scientific method which leads most scientists to conclude that there are no real disagreements between science and religion?

14. Our American Constitution guarantees "freedom of the press." In many European countries there is now a strict censorship of the press. Keeping the scientific method in mind, discuss the advantages and disadvantages of freedom and censorship of the press.

15. In a truly scientific study of a disease, what would a scientist do in order to determine what caused the disease?

16. In addition to the scientific method, how else might some people come to conclusions as to the cause of a given disease?

17. Consider some article which you have recently read in a weekly or monthly magazine. What reasons have you for believing the contents of the article to be true, or not true?

18. Why is it that newspapers do not go to as much trouble to make their statements accurate, as we have in this biology book?

19. Why are the articles in a newspaper so rarely signed?

20. Have you ever believed something on apparently good authority, and then found better authority for changing your belief? Explain.

21. Among the advertisements in magazines and newspapers find cases where "science" is quoted for its advertising value. Report to the class. Tell, in each case, whether the claims are scientifically sound or not.

22. Find two books on the same or closely similar subjects. Which is the better authority on the subject? Carefully compare the two books in preparing your answer.

23. If the biology textbook contains a statement which disagrees with your own observations, how would you determine which was correct? Think well about your answer!

24. How much of what you "know" about biology have you learned from "authority" and how much by direct observation? Write down your guess, and then work the next problem.

25. Study any five pages in this text that seem to you to contain particularly interesting material. Count the number of separate facts contained in them. Record the number that you have verified by your own first-hand observation. Record the number that seem to be based on the author's own observation? How much in those pages was based on second-hand or more remote authority?

26. What chapters in this biology text seem to be based entirely or very largely on first-hand observation?

27. Try to find a whole book, or an article in some magazine or journal, which is based *entirely* (or very nearly so) on first-hand observation.

28. Give one or more instances of a man who was not a biologist posing as an authority on a biologic subject?

29. Name some commonly accepted superstitions other than those given in this chapter.

30. Produce your scientific evidence that some commonly-held super-ion is not true.

31. Do you believe there are ghosts? Are you sure? Why?

32. Have you recently heard anyone complaining of "bad luck" or rejoicing over "good fortune," and implying that those things had come without very much reason?

33. Do you believe there is such a thing as "luck"? Carefully explain.

34. Recent books on spiritualism publish actual photographs of "spirits which have returned to the earth." Does this or does this not prove that ghosts really exist?

35. Are your actions *ever* based on superstitions? Which superstitions? Be honest in your reply!

36. Make a short list of things that you *wish* were true, although biologists have shown that they are not true. Be honest—we all wish the world were different in some way.

Courtesy Ind. State Conservation Dept.

FIG. 504.—AND COME AGAIN!

37. Give an instance of something that is beautiful but not scientifically true.

38. Give an instance of a scientifically established fact which is not beautiful and perhaps not good.

SELECT REFERENCE LIST

More extensive lists of references are given at the end of each of the seven sub-divisions of this text: Taxonomy, Distributional Biology, Morphology, Physiology, Genetics, Ecology, and Behavior. The following books constitute a select list covering all of these biologic sciences. They are recommended as especially valuable for student use.

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